REPORT NO. CASD-NAS 73-003
CONTRACT NAS 8-29150

(NASA-CR-124411) LIFE SCIENCES PAYLOAD DEFINITION AND INTEGRATION STUDY, TASK C AND D. VOLUME 1: MANAGEMENT SUMMARY (General Dynamics/Convair) 56 p HC $3.50 CSCL 14B G3/31

N73-32765

Unclas 15654

LIFE SCIENCES PAYLOAD DEFINITION AND INTEGRATION STUDY (TASK C & D)

VOLUME I ✦ MANAGEMENT SUMMARY

GENERAL DYNAMICS
Convair Aerospace Division

REPORT NO. CASD-NAS73-003

LIFE SCIENCES PAYLOAD DEFINITION AND INTEGRATION STUDY (TASK C & D)

VOLUME I ✦ MANAGEMENT SUMMARY

August 1973

Submitted to
National Aeronautics and Space Administration
GEORGE C. MARSHALL SPACE FLIGHT CENTER
Huntsville, Alabama

Prepared by
CONVAIR AEROSPACE DIVISION OF GENERAL DYNAMICS
San Diego, California

ACKNOWLEDGMENTS

This report consists of Volume I — Management Summary, Volume II — Payload Definition, Integration and Planning Studies, Volume III — Appendices, and Volume IV — Preliminary Equipment Item Specification Catalog.

The authors wish to express their appreciation to the entire Life Sciences Payload Integration Team composed of:

C. B. May, Contracting Officer's Representative, NASA/MSFC

R. W. Dunning	NASA/Headquarters
S. T. Taketa	NASA/Ames Research Center
J. A. Mason	NASA/Johnson Space Center

and to J. D. Hilchey, NASA/Marshall Space Flight Center, for their valuable assistance and cooperation throughout the entire course of this study.

The following General Dynamics Convair Aerospace personnel contributed to this program:

G. L. Drake (Contract Manager)
R. C. Armstrong (Convair Life Sciences Manager)
J. R. Murphy
F. G. Rivinius
E. J. Russ
W. G. Thomson
D. W. Vorbeck

Comments or requests for additional information should be directed to:

C. B. May
National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Huntsville, Alabama 35812
Telephone: (205) 453-3431

or

G. L. Drake
Convair Aerospace Division of General Dynamics
P. O. Box 80847, Mail Zone 663-00
San Diego, California 92138
Telephone: (714) 277-8900, Ext. 1881

PRECEDING PAGE BLANK NOT FILMED

TABLE OF CONTENTS

TABLE OF CONTENTS, Contd

TABLE OF CONTENTS, Contd

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

AAP	Apollo Applications Program
BEST	Bioexperiment Support & Transfer
BRSM	Bioresearch Support Module
cm	Cage Module
CORE	Common Operational Reserach Equipment
CVT	Concept Verification Test
DMS	Data Management System
EGG	Electrocardiogram
EC/LSS	Environmental Control/Life Support System
ECS	Environmental Control System
EI	Equipment Item
EPS	Electrical Power System
EU	Equipment Unit
FPE	Functional Program Element
HUM	Holding Unit Module
IMBLMS	Integrated Medical & Behavioral Laboratory Measurement System
LFB	Laminar Flow Bench
LSPD	Life Sciences Payload Definition
LS/PS	Life Support/Protective Systems
MSFN	Manned Space Flight Network
MSI	Man-Systems Integration
PCM	Pulse Code Modulated
PI	Principal Investigator
RAM	Research Applications Module
SRT	Supporting Research Technology
TCS	Thermal Control System

SECTION 1

INTRODUCTION AND SUMMARY

1.1 OBJECTIVES

The current NASA space program is being guided by overall objectives that include (1) obtaining greater scientific knowledge, and (2) hastening and expanding the practical application of space technology. The Life Sciences Payload Definition and Integration Study is an integral part of this NASA program.

The primary objectives of the payload definition and integration study were to:

a. Identify the research functions that must be performed aboard potential Life Sciences spacecraft laboratories and the equipment needed to support these functions (Task A, Figure 1-1).

b. Develop layouts and preliminary conceptual designs of several potential baseline payloads for the accomplishment of Life Sciences research in space (Task B, Figure 1-1).

c. Perform integration of the NASA -selected laboratory designs with the shuttle/ sortie module (Task C, Figure 1-1).

d. Update and develop costs that could be used by NASA for preliminary program planning (Task D, Figure 1-1).

1.2 BACKGROUND

The Life Sciences Payload Definition and Integration Study was originated in November 1970 as the Space Biology Payload Definition Study and was to cover all four tasks shown in Figure 1-1. After four and one-half months of activity (mid-point of Task B), the program scope was expanded to include all of Life Sciences. The added Functional Program Elements (FPEs) of biomedicine, life support protective systems, and man-system integration were then made a part of a redefined activity called the Life Sciences Payload Definition and Integration Study. The study was then structured to perform Task A and Task B (payload Definition Phase) under NASA contract (NAS8-26468) and Task C and Task D under contract NAS8-29150. The Task A and B study results included the establishment of research functions, equipment definitions, and conceptual baseline laboratory designs.

During Task A (Figure 1-1), the basic research requirements were obtained from NASA life scientists and, under their guidance, from various sources of information.

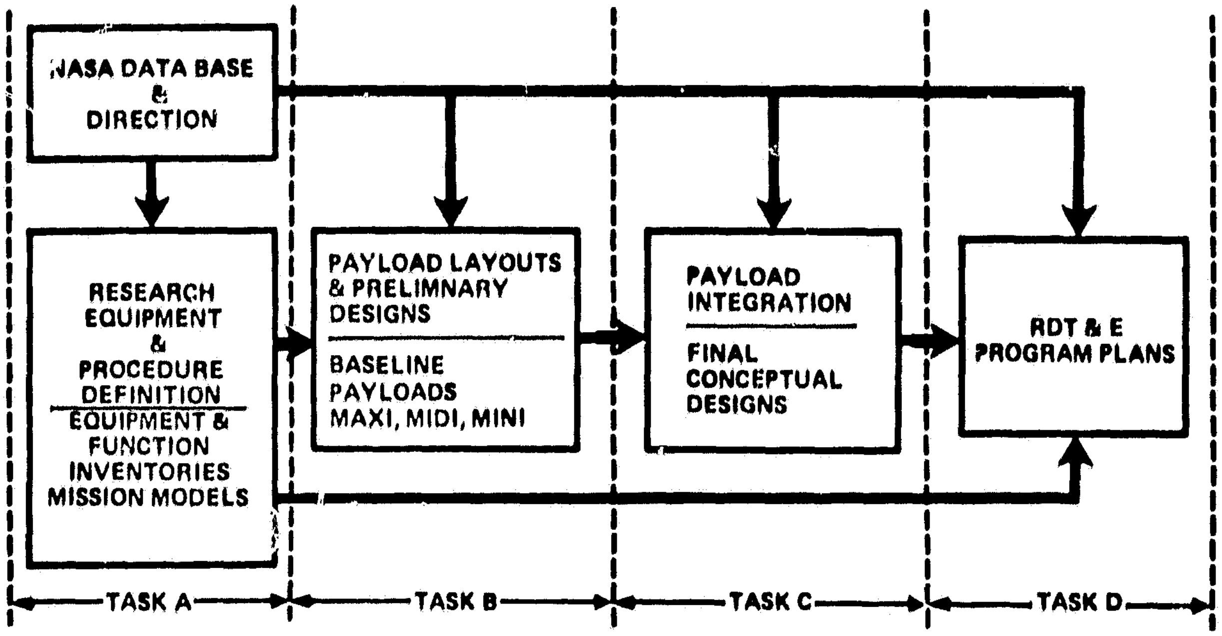


Figure 1-1. Program Overview

The disciplines included biology, medicine, man-systems integration, life support/protective systems, systems engineering and design. The NASA team members represented NASA Headquarters, Ames Research Center (ARC), Langley Research Center (LRC), Manned Spacecraft Center (MSC), and Marshall Space Flight Center (MSFC). The academic team members were on the staff of the University of California at San Diego. Convair Aerospace, representing industry, provided systems and design engineering as well as biological and medical capabilities.

This team used as a starting point the reports and findings of the candidate experiment selection activities previously accomplished by the various Life Sciences elements of NASA. The source material used to estimate the overall biology research capability requirements arises from the early 1960s and later when candidate experiment proposals (e.g., from Biosatellite, AAP, SR&T, and Experiment Survey Program, etc.) were initially evaluated. Scientific reviews of these proposals had been accomplished by various standing advisory and ad hoc panels operating for the NASA Office of Space Science and Applications (OSSA). The engineering feasibility and flight mission compatibility of the proposed experiments had been determined by NASA/ARC and MSC. After a final review, the Space Biology Subcommittee had recommended, over the years, a considerable number of experiments as candidates for flight. Some of these were chosen by OSSA for specific flights, but all of the candidate experiment outputs of this review and selection process served as the basic source material for this study. This base was supplemented by documentation from the Reference Earth Orbital Research and Applications and Investigations Study, the Earth Orbital Experiments Progarm and Requirements Study and the Biotechnology Laboratory Study.

From these data sources, inventories of functions (activities) and equipment necessary to conduct Life Sciences research in space were compiled. These inventories, containing pertinent information on the functions and equipment, were placed on computer cards in a format which permitted rapid printout and updating, as well as computer processing. In compiling the master inventories of functions and equipment, mission parameters and other constraints were purposely not imposed in order to obtain comprehensive inventories. The master inventories thus provided a reference as to the maximum reasonable content and capability of an idealized orbital Life Sciences facility. Any reduction from this functional or equipment capability, proposed for any reason, could be monitored by the scientist/managers and approved or denied.

During Task B, preliminary conceptual designs were developed for several potential Life Sciences payloads. The functions and equipment inventories were screened for each potential payload according to a particular set of payload criteria. Thus, listings of appropriate functions and equipment for each payload were obtained and used as the basis for the Task B design studies. Work was performed on preliminary conceptual design layouts, research crew operations analysis, preliminary cost specifications, and supporting subsystem conceptual designs.

Throughout the study, the general philosophy of the laboratory facility approach was followed. This term referes to the fact, herein, that Life Sciences Laboratory facility payloads, capable of a wide variety of experimentation, were developed rather than groupings of specific equipment designed to perform specific experiments. The experiments that might be accomplished in the time frame of the candidate payloads cannot be accurately defined at present. These experiments will depend on the experimental results of earlier flights. Also, the long mission duration of the advanced research laboratories requires that these laboratoreis be capable of accommodating completely unknown experiments. Therefore, it was essential that a laboratory facility approach be used to (1) prevent initallly locking onto specific experiments that later may prove unrealistic, and (2) permit flexibility in program planning by NASS Life Sciences administrators.

Other general guidelines used during the study included: (1) allowing the research requirements to dictate the payload characteristics with minimum constraints imposed by supporting mission and spacecraft, (2) use of evolutionary payload concepts to provide orderly growth from payloads with lesser capability to those with comprehensive capability, and (3) maintaining full responsiveness to the broad desires of the life scientists. The research requirements were emphasized, and engineering design concepts to meet these requirements were defined. This resulted in some payloads with broad capability that were completely responsive to all the scientists' desires. These comprehensive laboratories were used as reference payloads, from which lesser capability payloads were defined with appropriate reduction in scientific responsiveness.

It is important to note that, having defined the maximum research capability requirement predictable from current knowledge, it is now possible to maintain accountability for all reductions in research capability due to any tradeoffs. This detailed accounting permitted the scientist/managers to confirm or refuse any specific capability reduction suggested by designers, since the scientist was kept fully aware of specific functions lost by modification or deletion of a given equipment item. Thus, maximum responsiveness to scientists' needs was maintained, and the direction of integration planning impact is from science requirement upon design response.

The above comprehensive laboratories were referred to as maximum laboratorois or payloads. They were to be supported by Research Application Modules (RAMs) predecessor to the present sortie module concept) attached to a space station operating in a time period beyond 1980. The payloads with decreased capability were referred to as minimum laboratores or payloads. These were generally supported by a RAM payload module and a RAM support module operating in a shuttle sortie mode (1978 to 1980 time period). Support of the minimum payloads by Skylabs were also considered, but this option was dropped early in the study.

The final output of Task B was a set of four baseline preliminary conceptual design payloads. These are briefly described below.

a. The maximum laboratory (Maxi-Max) is the reference baseline payload providing full Life sciences research capability. It can support research on large numbers of biological organisms to provide many simultaneous experiments yielding statistically valid results. Biomedical, man-systems integration (MSI), and life support and protective systems (LSPS) research can also be fully supported. This laboratory was not constrained by practical considerations, since it was intended only as reference payload, not to be flown. Most facilities that were suggested or desired by the research scientists were included. Broad capability scientific instruments, rather than special purpose instruments, were included to yield the maximum scientific return. A large dual-purpose centrifuge was postulated as required to accommodate human, biological, and technological research using 1 g controls and various g levels from 0 - 1 g for test purposes.

b. The Maximum Nominal laboratory (Maxi-Nom) is foreseen as the most comprehensive laboratory that could actually be flown with the space station complex (Figure 1-2). Its biomedical research capability is equivalent to the Maxi-Max, including all mandatory, highly desirable, and desired research functions. Only the mandatory and highly desired functions are incorporated in the areas of life support and protective systems, man-system integration and biology. However, the laboratory can support primates, small vertebrates, invertebrates, cells and tissues, and plants in sufficient quantities to provide statistically valid results on several

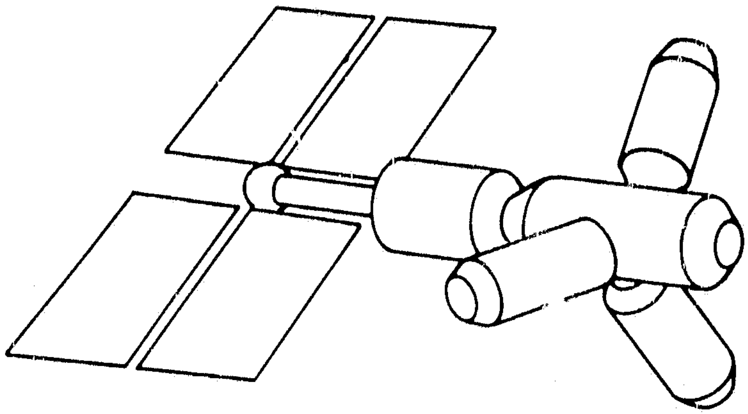


Figure 1-2. Space Station Configuration (for the Maxi-Nom and Growth Version Mini-30 Baseline Laboratories

simultaneous experiments. The laboratory contains an internal centrifuge for biology studies. Research operations are semi-automatic, where possible, to reduce crew time requirements. On-board analysis is featured to minimize delay in obtaining near-real-time experiment results.

c. The Minimum-30 payload (Mini-30) is applicable to an initial space station mission as well as the 30 day RAM/shuttle sortie flights (Figures 1-2 and 1-3). For a space station mission duration of one year, the Mini-30 laboratory could operate on a 30-day resupply basis. Operation with the RAM/shuttle sortie would be for 30 days, but the laboratory could be used for multiple flights and experiments in series. Biomedical and life support and protective systems research capabilities accommodate both the mandatory and highly desirable functions. Man-system integration and biology are supported only at the mandatory level of function. Ground analysis of specimens taken in space is used where possible to minimize equipment and the crew work load. No centrifuge is provided with this payload.

d. The Minimum-7 payload (Mini-7) would operate in a RAM/shuttle sortie mode of 7 days total mission duration. The laboratory equipment would be reusable for multiple flights and experiments. For this round of payload definition, the biomedical research capability was omitted from this particular payload at the direction of the scientist/managers. (It was later added to the payload during Task C.) However, biomedical monitoring and flight support were assumed to be aboard as a distinctive operational feature and function of the sortie mission, but not included in, nor assessed against, the research payload. The remaining areas of Life Sciences research functions were included at the level, mandatory.

Individual experiments in man-system integration and life support and protective systems can be accommodated by the Mini-7 laboratory for each sortie. The biology equipment will support research on cells and tissues, invertebrates and plants. No centrifuge is provided, and samples taken in orbit will be returned to earth for analysis.

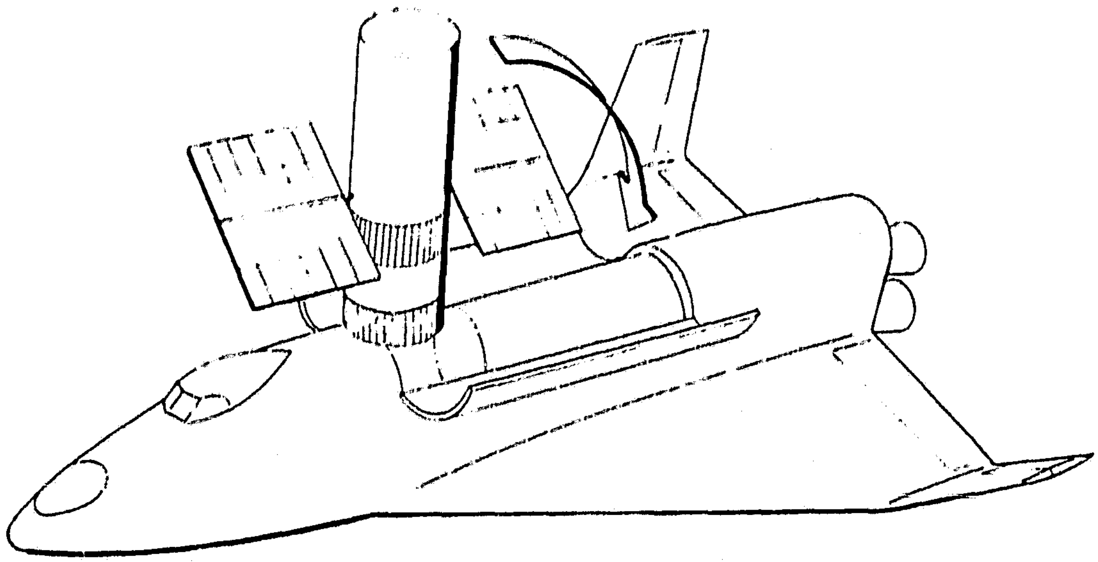


Figure 1-3. RAM/Shuttle Sortie Configuration (for Mini-30 and Mini-7 Baseline Payloads)

The outputs of Tasks A and B were used by the NASA Life Sciences Integration Team to establish guidelines for Tasks C and D, the laboratory integration phase of the study described in the following sections of this summary report.

1.3 DEFINITIONS

The following paragraphs describe the more important definitions used in this study. The Life Sciences discipline encompasses the functional program elements (FPE) of biomedicine, vertebrates, invertebrates, plants, and cells and tissues, man-systems integration, and life support and protective systems. The FPEs describe the grouping of experiments or experiment classes characterized by mutually supportive areas of research, which impose similar demands on the support module systems.

1.3.1 LIFE SCIENCES. Life Sciences research includes biomedicine, biology, man-systems integration, and life support/protective systems:

a. Biomedicine — Research devoted to (1) understanding character, time course and mechanisms of the physiological, anatomical, behavioral, and functional changes in man exposed to the space environment; and (2) providing the criteria for countermeasures in support of manned space flights.

b. Biology — Research devoted to (1) understanding the mechanisms of significant changes induced by the space environment on animals and cells and tissues as models wherein the investigation cannot be done easily on man; (2) understanding the graviperceptive mechanism and the role of gravity and biological periodicities (as influenced by time-varying environmental parameters) on various biological processes at the subcellular, cellular, tissue, organ, and organism levels; and (3) determining the biological effectiveness of galactic high-Z cosmic radiation particles. For the purpose of this study, biology will encompass research using vertebrates, invertebrates, plants, and cells and tissues as test subjects.

c. Man-System Integration (MSI) — Research devoted to (1) obtaining data on crew performance, integrated crew/equipment operations, and habitability; and (2) obtaining data to optimize man's ability to live and work in space.

d. Life Support and Protective Systems (LS/PS) — Research devoted to (1) obtaining data for advanced design of life support systems (LSS) and protective systems components and subsystems; (2) the establishment of design criteria,and (3) the development of the technology that will enable man to accomplish space missions effectively and safely.

1.3.2 LABORATORY EQUIPMENT ELEMENTS.

a. Equipment Item (EI) is the smallest hardware element defined within the various laboratories. In some cases an EI (such as a gas chromatograph) contains many individual components while other EI's are quite simple, such as a thermocouple.

b. Equipment Unit (EU) is a functional grouping of related equipment items. As an example, the items within the biochemical and biophysical EU include a gas chromatograph, mass spectrometer, and an atomic absorption spectrophotometer.

c. Common Operational Research Equipment (CORE) — Equipment or facility that serves many experimental areas in several Life Sciences FPEs. Examples are spectrophotometer, microscope, centrifuge, specimen preparation facility, and sample preservation units.

d. FPE-peculiar equipment — General-purpose equipment unique to a given Life Sciences FPE that can support various experiments on a reusable basis. Examples are the lower body negative pressure device, MSI task board, small vertebrate holding unit, and plant holding unit.

e. Experiment-peculiar equipment — Equipment designed specifically to support a given experiment and which is considered not to be reusable for another experiment without modification.

1.3.3 LABORATORY PAYLOADS DEFINED.

a. Shared 7-Day is a Life Sciences laboratory occupying approximately one-half the volume of a sortie module. The other half of the sortie module would be used by another scientific discipline.

b. Dedicated 7-Day is a laboratory (sortie module) devoted entirely to research in the Life Sciences area. The sortie module mission duration is seven days.

c. Dedicated 30-Day is a laboratory (sortie module) basically the same as the Dedicated 7-Day except that the mission duration is 30 days.

d. Carry-On Laboratories are portable, primarily self-contained Life Sciences laboratories that can be placed in the sortie module or the crew compartment of the shuttle orbiter.

1.4 TASK C AND D OBJECTIVES

The primary objective of Task C was to determine the compatibility of the selected baseline laboratories with the shuttle/sortie module concept. The initial activity involved updating the laboratories' functional capabilities and related equipment items as directed by the NASA Life Sciences Payload Integration Team. The specifics of this NASA-guidance is covered in the following paragraphs. The second task of the compatibility analysis established the size and characteristics of the various sortie module subsystem (i.e., electrical power, crew EC/LSS) required to support the defined research capability of the baseline laboratories.

Task D was aimed at defining preliminary program plans. This activity involved the determination of equipment cost profiles and development schedules to support flight opportunities during 1979 and beyond. Areas of significant supporting research and technology (SRT) were also identified.

1.4.1 FUNCTIONAL CAPABILITY. The NASA review of the Task A and B outputs resulted in establishing the Mini-30 Laboratory as the area for primary emphasis. The equipment and research functions called out for this laboratory concept would provide the basic capability of both the Dedicated 7-Day and Dedicated 30-Day Laboratories. Secondary emphasis was placed upon the Shared 7-Day Laboratory. The Shared 7-Day Laboratory was based upon the Task A & B Mini-7 payload modified to include a factored-down Mini-30 capability in the areas of biomedical and vertebrate research and removal of the EVA research capability.

A second general category of research capability was described as the Carry-On Laboratories. Since the laboratories had not been studied during Task A & B, only conceptual designs were to be developed.

1.4.2 SORTIE MODULE. Some of the more significant sortie module characteristics used during this study are summarized in Table 1-1.

1.5 CONDUCT OF THE STUDY

The approach used to define the integration and planning activity associated with the Sciences Laboratories is shown in Figure 1-4. It includes (1) definition of research

equipment, (2) review of sortie module resources available to support the research equipment, and (3) definition of additional subsystem equipment to be used to support the research equipment. These three activities led to the definition of preliminary laboratories and the generation of planning information such as costs and schedules. In defining the research equipment requirements of these laboratories, the equipment was grouped according to its function, and an equipment unit (EU) data package was formulated. The (EU) data package is described in Section 2 of this report.

Table 1-1. Summary of Sortie Module Characteristics

Parameter	Description	
Internal Volume	87.8 m^3	(3,100 ft^3)
Diameter	4.26 m	(14 ft)
Length	7.31 m	(24 ft)
Allowable Payload	5,450 kg	(12,000 lb)
Average Power Available	4-5kW	
Electrical Energy	150 kW-hr	
Heat Rejection	4-5 kW_t	
Data Acquisition Rate	100 kbps	
Data Downlink Rate*	25-256 kbps	
Crew Size Accommodations		
Total in Orbit	4	
Sortie Module	2	

*Payload use is within this range; actual rate is dependent on shuttle orbiter use.

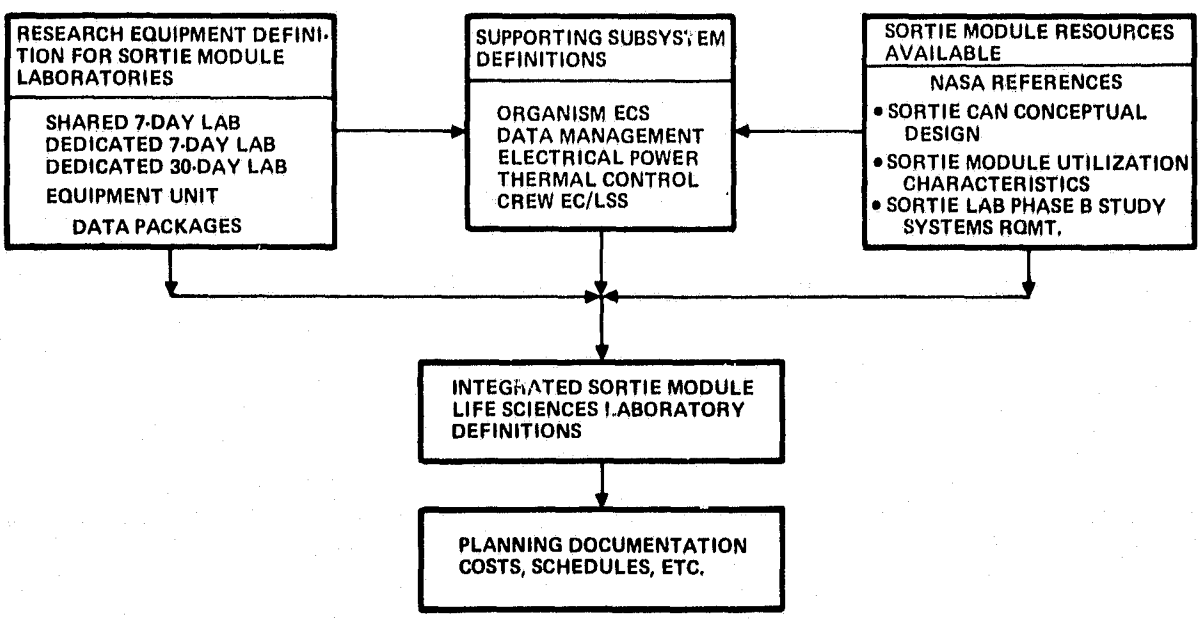


Figure 1-4. Laboratory Integration Study Flow Chart

Essential to the operational use of the research equipment are the organism ECS, data management, electrical power, thermal control and crew EC/LSS. These supporting subsystems were defined with respect to the research equipment requirements and the existing subsystems aboard the sortie module.

From the research equipment and subsystems studies, integrated laboratory definitions including layout drawings and overall laboratory properties were determined. Costs and schedules necessary for the orderly development of Life Sciences Laboratoreis were then estimated.

SECTION 2

RESEARCH EQUIPMENT DEFINITION FOR SORTIE MODULE LABORATORIES

2.1 EQUIPMENT UNIT DATA PACKAGES

The research equipment needed aboard the Shared 7-Day Laboratory, the Dedicated 7-Day Laboratory, and the Dedicated 30-Day Laboratory is described in what is referred to in this report as equipment unit data packages. This section describes, first, the basis of the equipment groupings used in establishing these data packages and, second, the content of the data packages.

2.1.1 EQUIPMENT UNIT GROUPS. The previous contract described in Section 1.2 of this volume resulted in functions, equipment items (EI), and equipment units (EU) necessary for the performance of Life Sciences research in space. The functions are specific activities that must be performed while pursuing Life Sciences research such as urine analysis, organism subculturing, and blood preparation. The equipment items (EI) are those individual pieces of hardware necessary to perform the specific research functions, such as a spectrometer, medical-surgical kit, metabolic analyzer, and centrifuge. Equipment units (EU) are comprised of equipment items (EI) that pertain to the performance of common but generalized functions such as preparation and preservation of organisms and specimens, or biomedical research support.

Since there were approximately 200 equipment items (EI) needed to perform Life Sciences research in the sortie module laboratories, it was convenient to use the equipment units (EU) for the identification of laboratory properties. Twenty-two EUs are required for the laboratories, and the numbers of EIs within these range from about three to 30. Where several of these EUs had only a few EIs, or they were related or similar in nature, they were further grouped together for the purpose of specifying the data. One example is the Maintenance, Repair, and Fabrication Unit (EU No. 6, containing 13 EIs) and the Ancillary Storage Unit (EU No. 7 containing 3 EIs); see Table 2-1. Another example of an EU grouping is the Small Vertebrate Holding Unit (EU No. 40 containing five EIs), the Primate Holding Unit (EU No. 41 containing three EIs), and the Vertebrate Research Support Unit (EU No. 42 containing three EIs). In all, there are 14 equipment units or equipment unit groups for which data packages were prepared. These are shown in Table 2-1. The equipment units that pertain to general laboratory operations required by all the FPEs are designated common operational research equipment (CORE), and the others are designated FPE (functional program element) specific. These designations were derived in earlier studies and their use was continued in this study (see Section 1.3 of this of this volume for definitions).

Table 2-1. Laboratory Equipment Unit Groups

EU No.	Name	
1	Visual Records & Microscopy Unit	Core Units
2	Data Management Unit	Core Units
3	Life Sciences Experiment Support Unit	Core Units
4	Preparation & Preservation Unit	Core Units
5	Biochemical & Biophysics Analysis Unit	Core Units
6/7	Maintenance Repair & Fabrication Unit/Ancillary Storage Unit	Core Units
11	Airlock/EVA Capability	FPE Specific Units
12/31	Biomedical/Behavorial Research Support Unit/ Biomedical Research Support Unit	FPE Specific Units
26	Radiobiology Support Unit	FPE Specific Units
40/41/42	Vertebrate Holding Unit/Primate Holding Unit/ Vertebrate Research Support Unit	FPE Specific Units
50/51/70	Plant Holding Unit/Plant Research Support Unit & Invertebrate Holding Unit	FPE Specific Units
60/61	Cells & Tissue Holding Unit/Cells & Tissues Research Support Unit	FPE Specific Units
80	Life Support Subsystem Test Unit	FPE Specific Units
91/93	Behavioral Measurements Unit/Mobility Unit	FPE Specific Units

2.1.2 CONTENT OF THE EQUIPMENT UNIT DATA PACKAGES. Shown below is an outline of the information to be found in the data packages in Volume III.

1. EU Functional Capability and Summary Data

   Summary of Weight, Power, Volume and Cost

2. Equipment Items

   Equipment List
   Equipment Volume and Placement Figures

3. Operations & Interface Data

   Equipment Operations Analysis
   Data Requirements
   Consumables
   Launch & Re-entry Operations
   Electrical Power
   Heat Rejection
   Typical Equipment Unit Functional Interfaces

4. Equipment Item Cost Summary

1. EU Functional Capability and Summary Data. This category is summary information containing a statement of the general functional capability of the EU and a table of total weight, power, volume and cost.

2. Equipment Items. Within this category is detailed information about each equipment item (EI). This includes a listing of all the EIs along with their pertinent properties, and sketches showing the volume and placement of these EIs within standardized racks and consoles.

3. Operations and Interfaces. The major information contained in this category is the analytical equipment operations model. Such a model was necessary because of the NASA guideline to use a facility approach to the definition of the Life Sciences Laboratories. That is, specific experiments were not to be used as the basis for laboratory design. Instead, the laboratories were to be designed as general facilities capable of supporting a broad range of experiments. The operations model was based upon the functions to be performed within the laboratories as determined during Task A and B of the preceding contract for the Mini-30 and Mini-7 Laboratories, and slightly modified to correspond to the current NASA desires for the Shared 7-Day and Dedicated 30-Day Sortie Module Laboratories. Each of the functions requires the use of specific EIs within the laboratory and also requires a specific amount of crew time for the performance of the function. This information is contained in the functions inventories for each laboratory. The operations model was formed by using these times in addition to an assumed frequency for the occurrence of each function. This information was then used to calculate crew time requirements and equipment usage times associated with each function. Crew time totals were used to calculate the number of payload specialists required for Life Sciences experiment operations. Equipment usage times were used to calculate EI power consumption and average total power required by the laboratories.

Also under the heading of Operations and Interfaces are other data as indicated in the listing above. Included are the data requirements of the EIs, general information on any EIs requiring special consideration during launch or re-entry, and information on the consumables required within the EU. Electrical power and heat rejection requirements of the equipment are presented, and typical research functional interrelationships between the various EUs are also described.

4. Equipment Item Cost Summary. The cost summary table indicates the type of development required as well as the time required for the development of a flight article. Each of the three sortie module laboratories is listed with unit and development costs for each individual EI and a summation for the total EU cost. Commercial costs for certain EI are listed for comparison. When appropriate, remarks pertaining to the cost factors of an EI are included in the table.

2.2 GENERAL DESCRIPTION OF RESEARCH EQUIPMENT

The following sections are brief descriptions of the functional capabilities and major EIs within each EU or EU group for which there is a data package in Volume III.

2.2.1 EQUIPMENT UNIT 1 - VISUAL RECORDS AND MICROSCOPY UNIT. This equipment unit provides the capability for obtaining and preserving records of visual experiment phenomena and data. Major equipment items include movie cameras, still cameras, video cameras, a biomedical recorder and microscopes.

2.2.2 EQUIPMENT UNIT 2 - DATA MANAGEMENT UNIT. The equipment within this EU is intended to supplement the sortie laboratory data management subsystem (DMS) to provide the full capability necessary to perform the Life Sciences reserach. Equipment in this EU includes a CRT camera, portable interrogative display and keyboard, and a portable oscilloscope.

2.2.3 EQUIPMENT UNIT 3 - LIFE SCIENCES EXPERIMENT SUPPORT UNIT. This unit is intended to provide centralized supporting and vehicle interface equipment for the Life Sciences payloads. Major equipment includes crew mobility aids, crew restraints, small gas storage bottles, and waste storage.

2.2.4 EQUIPMENT UNIT 4 - PREPARATION AND PRESERVATION UNIT. This equipment unit provides the capability for the preparation and preservation of medical/biological specimens and whole organisms. Preparation encompasses all of the operations necessary for (1) obtaining and preparing specimens for on-board analysis (when required, this is usually done by using the equipment within the biochemical/biophysics analysis unit), and (2) preparing specimens or organisms for preservation and return to ground. This includes operations such as autopsies, dissections, centrifugation, anesthetization, staining, substrate preparation, and sterilization. Preservation operations include freezing, lyophilization, and fixation.

Major equipment items include the laminar flow bench, centrifuges, refrigerators, freezers, various kits, and mass measurement devices and chemicals.

2.2.5 EQUIPMENT UNIT 5 - BIOCHEMICAL/BIOPHYSICAL ANALYSIS UNIT. This unit performs the major measurements and analyses of experiment specimens and parameters, generally requiring more than simple instrumentation. These include measurements of blood and urine constituents and properties, gas compositions, and sound levels. Major equipment items include an automatic blood analyzer, spectrophotometer, blood cell counter, blood gas analyzer, mass spectrometer, and gas chromatograph.

2.2.6 EQUIPMENT UNIT GROUP 6/7 - MAINTENANCE, REPAIR AND FABRICATION UNIT (6) AND ANCILLARY STORAGE UNIT (7). Equipment Unit 6 is intended to provide for maintenance, repair, or fabrication of payload equipment. For the short

7- and 30-day missions under consideration for the sortie module, the primary emphasis is one of maintenance, with minor capability for repair and fabrication. Major equipment items in EU 6 include a hand cleansing and sterilization device, waste solids compactor, clean-up kit, tool kit, and electronic equipment for the maintenance and calibration of electrophysiological sensors. Equipment Unit 7 is ancillary storage space primarily for consumable items.

2.2.7 EQUIPMENT UNIT 11 - AIRLOCK AND EVA CAPABILITY. This equipment unit includes the major items required for EVA activities in support of Life Sciences testing. By NASA direction, EVA test activities will not be performed aboard the Shared 7-Day Laboratory. Therefore, EVA equipment is needed only aboard the dedicated laboratories. This equipment unit includes an air lock, teleoperator control console, and pressure suits. The shuttle orbiter airlock will be used for EVA.

2.2.8 EQUIPMENT UNIT/GROUP 12/31 - BIOMEDICAL/BEHAVIORAL RESEARCH SUPPORT UNIT (12), AND BIOMEDICAL RESEARCH SUPPORT UNIT (31). These equipment units contain equipment intended to provide the functions necessary for behavioral and biomedical research. Equipment Unit 31 contains equipment necessary for biomedical research but not needed for behavioral research. Equipment Unit 12 contains equipment necessary for both behavioral and biomedical research. Major equipment items in EU 12/31 are the body mass measurement device, experimenter's control console, electrophysiology display, rotating litter chair, and bicycle ergometer.

2.2.9 EQUIPMENT UNIT 26 - RADIOBIOLOGY SUPPORT UNIT. This unit supports radiobiological studies and provides the capability for irradiating organisms or specimens, and measuring radioisotype tracers. Major equipment items are the radiation detector, radiation source and radiation source storage (in the Dedicated 30-Day Laboratory only), and radiation counter.

2.2.10 EQUIPMENT UNIT/GROUP 40/41/42 - SMALL VERTEBRATE HOLDING UNIT (40), PRIMATE HOLDING UNIT (41), VERTEBRATE RESEARCH SUPPORT UNIT (42). This equipment unit provides for confining vertebrates as well as for research supporting functions specific to the vertebrate organisms. The environmental control equipment necessary for the support of the vertebrates is presented separately in Section 3.1 of this report. Major equipment items include two vertebrate cage modules, two primate cages (dedicated laboratories only), and metabolic mass balance measuring equipment.

2.2.11 EQUIPMENT UNIT GROUP 50/51/70 - PLANT HOLDING UNIT (50), PLANT RESEARCH SUPPORT UNIT (51), AND INVERTEBRATE HOLDING UNIT (70). These equipment units provide the environmental enclosures for the growth of plant and invertebrate organisms, and the equipment to support plant research. Experiment items include the plant and invertebrate holding units (cage modules), an enclosure for making metabolic mass balance measurements on plants, a clinostat, a plant tool kit, and an insect manipulation tool kit.

2.2.12 EQUIPMENT UNIT GROUP 60/61 - CELLS AND TISSUES HOLDING UNIT (60), AND CELLS AND TISSUES RESEARCH SUPPORT UNIT (61). These EUs provide for containing cells and tissues as well as supporting research in this area. The major EIs are the two holding units (cage modules) for cells and tissues.

2.2.13 EQUIPMENT UNIT 80 - LIFE SUPPORT SUBSYSTEM TEST UNIT. This EU provides the capability to perform tests on LSS prototype equipment. Major equipment includes portable life support systems for EVA, and an LSS test bench. The latter is intended to provide electrical power, coolant fluid, structural support, vacuum connections, and general-purpose instrumentation for a variety of experimental test apparatus.

2.2.14 EQUIPMENT UNIT GROUP 91/93 - MAN-SYSTEMS INTEGRATION (MSI) MEASUREMENTS UNIT (91), AND MOBILITY UNIT (93). These EUs provide the capability to test man's behavior and performance in space and his interaction with various types of equipment. Major EIs are the psychomotor performance console, the force/torque measurement taskboard, the vision tester, protective corridor devices, and the EVA, MSI task simulator (required only on the dedicated laboratories).

2.3 SUMMARY DATA FOR RESEARCH EQUIPMENT

The weight, power, and volume characteristics of the research equipment within the Life Sciences Laboratories are summarized in Table 2-2. The number of racks and consoles (combined) required for the research equipment aboard each of the laboratories is also indicated in the table. A weight allowance of 30 kg each has been added for these racks and consoles. It should be noted that the total number of racks and consoles aboard the Dedicated 7-Day and Dedicated 30-Day Laboratories is 11 and 13, respectively, rather than the 10 and 12 shown in the table. This is due to the addition of one rack in each laboratory for data management subsystem equipment (not included in the category of research equipment). The data management subsystem is discussed in Section 3.2 of this volume.

The weight of the research equipment aboard each laboratory is given in the table. The weight of the Dedicated 7-Day Laboratory increases over that of the Shared Laboratory because of a substantial increase in research equipment. The Dedicated 30-Day Laboratory weight increases over the Dedicated 7-Day Laboratory because of a slight increasd in research capability, but mainly because of the extra consumables required.

The volume shown in Table 2-2 is divided into that required for the racks and consoles and that required for distributed and extra EIs. The standard sized racks and consoles (0.61 × 0.61 × 2.0 meters) developed during Tasks A & B were used to house the research equipment. Examples of distributed EIs are crew mobility aids and gas manifolds, and examples of extra EIs are the rotating litter chair and organism holding units. These items are clearly not amenable to placement in racks and consoles. The volume of the racks and consoles added to the volume of the distributed and extra EIs makes up the total research equipment volume in the laboratories.

Table 2-2. Summary of Research Equipment Weight, Volume and Power

Property	Shared 7-Day Lab.	Dedicated 7-Day Lab.	Dedicated 30-Day Lab.
Number of Racks and Consoles Required for Research Equipment	7	10	12
Weight, kg (lb)			
Research Equipment	1974(4343)	3000(6600)	3724(8193)
Racks and Consoles	210(462)	300(660)	360(792)
Total	2184(4805)	3300(7260)	4084(8985)
Volume, m^3 (ft^3)	5.21(184)	7.44(263)	8.93(316)
Racks and Consoles	6.97(246	9.22(326)	9.60(339)
Distributed and Extra Items			
Total	12.18(430)	16.66(589)	18.53(655)
Average Electrical Power, kW	1.13	1.59	1.90
On-Duty* Average	1.25	1.80	2.12
Off-Duty* Average	1.02	1.39	1.68
*12-Hour Period			

The 24-hour average power requirements for all the research equipment were based on the equipment operations model and are shown in the table. The on-duty and off-duty averages are also shown and are based upon 12-hour on- and off-duty periods. These average power values were used in preliminary calculations on electrical power subsystem fuel requirements and thermal control subsystem loads.

SECTION 3

SUPPORTING SUBSYSTEM DEFINITIONS

In the preceding section, the research equipment contained in the Shared 7-Day, Dedicated 7-Day, and Dedicated 30-Day Laboratories was discussed. These laboratories and their equipment are contained in and supported by the sortie module. The sortie module contains certain baseline subsystems to supply electrical power, data management, and thermal control support to the research equipment and processes. These subsystems were reviewed during this study to determine whether the baseline sortie module could adequately support the Life Sciences Laboratories, or whether added subsystem capacity was needed. In addition to the baseline sortie module subsystems, an organism environmental control subsystem (ECS) is needed for the organisms aboard the laboratories, and the crew EC/LSS aboard the shuttle orbiter must provide for the crew requirements of the Life Sciences Laboratories. These two subsystems were also studied. The results of the various subsystem studies are summarized below.

3.1 ORGANISM ENVIRONMENTAL CONTROL SUBSYSTEM

An organism environmental control subsystem (ECS) separate from the crew ECS was used to provide isolation between the organisms and the crew. The term "organism ECS" rather than "organism EC/LSS" is used in this report, since the subject subsystem is devoted primarily to environmental control functions rather than life support functions such as food and waste management. The latter functions are provided as part of the organism holding units.

The design of this ECS depends upon the number of organisms aboard the Life Sciences Laboratories and their metabolic requirements. The total quantities of the smaller organisms were based on the multiples that could be housed in a standard organism holding unit which is referred to as a cage module. The cage module concept has been developed by General Dynamics Convair Aerospace and can be used, with modifications, to house small vertebrates, invertebrates, plants, or cells/tissues. It is essentially a closed cabinet, ventilated by the organism ECS to minimize contamination of the manned compartment of the sortie module. The closed cage module can also provide isolation between different groups of experiment organisms. The cage module is shown in Figure 3-1. It contains eight cages for rats, houses the electronic signal conditioners for the bioinstrumentation, and contains other electronic equipment for control of the cage moduel internal environment and other parameters.

Table 3-1 indicates the organism load aboard each of the three Life Sciences Laboratories. The Shared 7-Day Laboratory contains six cage modules for small vertebrates, invertebrates, plants, and cells/tissues. The dedicated laboratories contain

the same, with the addition of two primate containers (cages). The type and quantity of organisms indicated in the table for each cage module and the primate containers were used as the basis for the ECS design calculations.

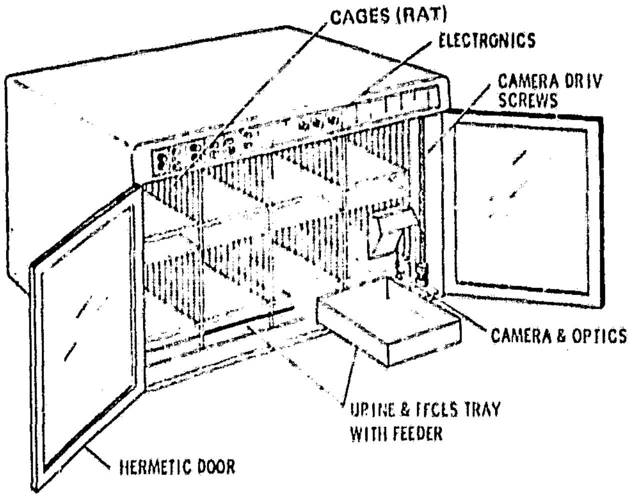


Figure 3-1. Cage Module

The plant, invertebrate, and cells and tissues loads are negligibly small compared to the vertebrate loads. The weights of the pertinent metabolic consumables for the vertebrates are shown in the lower part of Table 3-1. These small quantities do not warrant the use of regenerative type ECS components. The amount of water is the largest consumable and is stored aboard the laboratory.

The major ECS equipment is that required for conditioning the air flowing to the vertebrate holding units. A block diagram of the concept of this loop, which was formulated during the study, is shown in Figure 3-2. The loop incorporates high pressure O_2, a cooler-condensor for temperature and humidity control, LiOH for CO_2 removal, and blowers for circulation. It is compatible with short mission durations of up to 30 days, where the use of consumables such as lithium hydroxide (LiOH) and stored water are not prohibitively heavy and bulky.

Table 3-1. Organism ECS Loads Aboard the Life Sciences Laboratories.

	Shared 7-Day Lab	Dedicated 7-Day Lab	Dedicated 30-Day Lab
A. Organism Capacity			
Cage Modules			
Small vertebrates (16 rats)	2	2	3
Invertebrates (fruit flies)	1	1	1
Plants (marigolds)	1	1	1
Cells/tissues (rat tissue)	2	2	2
Total Cage Modules	6	6	6
Primate Containers (2 Macaques)	0	2	2
B. EC/LSS Consumables required to support organisms (16 rats and 2 small primates)*			
Oxygen, kg	2.0	4.9	21.0
Lithium Hydroxide, kg	3.2	7.7	32.8
Food, kg	1.5	3.6	15.5
Water, kg	4.9	12.5	53.7

* The consumables for plants, cells/tissues, and invertebrates are negligible compared to those required for these vertebrates. The Shared 7-Day Lab contains only 16 rats.

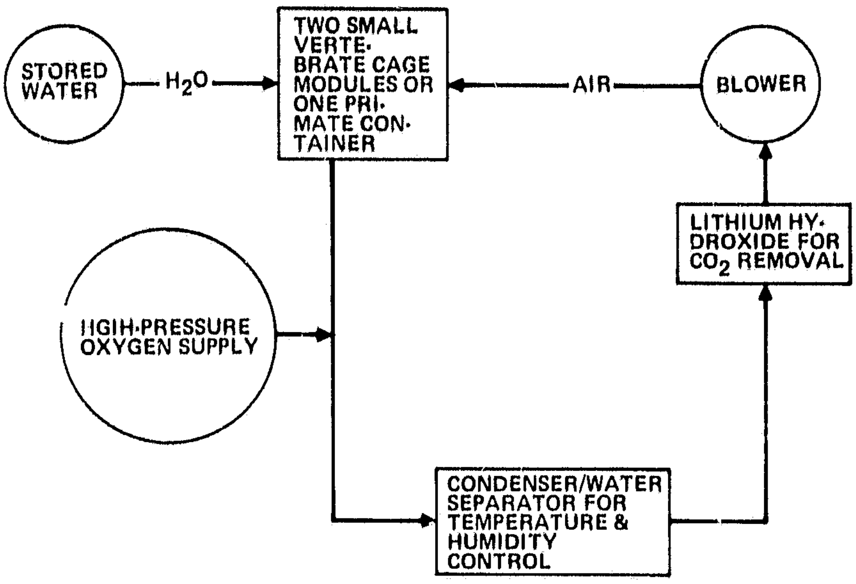


Figure 3-2. Block Diagram of ECS Loop Concept for Vertebrate Holding Units

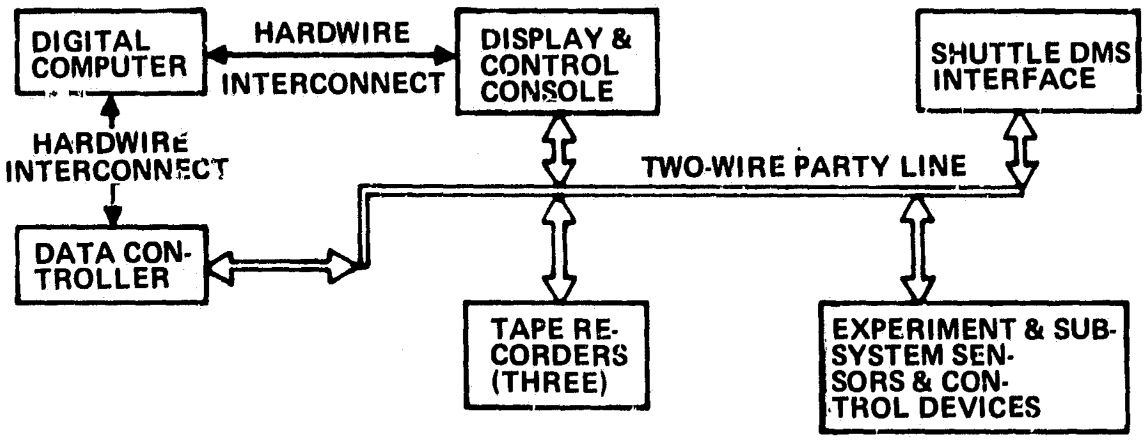
The ECS loop was sized to support two cage modules containing rats or one primate container. Thus, the Shared 7-Day Laboratory would contain one such loop and the Dedicated Laboratories would contain three such loops. In addition, a single loop similar to the vertebrate loop but much lower in capacity, is used by each of the laboratories for the ventilation of the plant, invertebrate, and cells/tissues cage modules.

3.2 DATA MANAGEMENT SUBSYSTEM

The sortie module contains a baseline data management subsystem (DMS), a block diagram of which is shown in Figure 3-3. A mini-computer is provided for experiment control and data processing. A display and control console contains cathode ray tubes, a multifunction display (displays video or symbols), and various control devices. Three standard types of tape recorders are available for use. These are a large-capacity recorder, a medium-capacity recorder, and a special-purpose video recorder. Data acquisition and control signals are transmitted serially to and from the experiment and subsystem sensors and control devices throughout the laboratory via a two-wire party system. The signals are controlled according to a predetermined schedule and format, but can be varied if desired by the crew. The maximum party line system bit rate is 100 kbps.

The sampled data rate requirements for the Dedicated 7-Day Laboratory, Table 3-2, were analyzed to scope the Life Sciences Laboratory requirements and compare them to the sortie module DMS capability. The Dedicated 7-Day Laboratory was the laboratory chosen for this analysis since it was the laboratory emphasized through the study. Also, it contains approximately the same equipment as the Dedicated 30-Day

Laboratory and will therefore require about the same amount of sampled data processing. The Shared 7-Day Laboratory data rates were not estimated but will be less than that for the Dedicated 7-Day Laboratory. They would have to be added to those of the sharing payload before determining whether they were compatible with the sortie module.



MAX PARTY LINE BIT RATE: 100 kbps

Figure 3-3. Sortie Module/Life Sciences Laboratory Data Management Subsystem Block Diagram

Table 3-2. Sampled Data Rate Requirements, Dedicated 7-Day Laboratory

EU	EU Name	Total (M bits per day)	
1	Visual Records	43	
2	Data Management	1,313	
3	Life Sciences Exper. Support	958	
4	Preparation and Preservation	7	
5	Biochemistry/Biophysics Analysis	67	
6/7	Maintenance and Storage	0	
11	Airlock and EVA	negl.	
12/31	Biomedical/Behavioral Research Support	186	
26	Radiobiology Support	negl.	
40/41/42	Vertebrate Holding and Support	3	
50/51/70	Plant Holding and Support/Invertebrates	1	
60/61	Cells and Tissues	1	
80	Life Support Subsystem Test Unit	2	
91/93	MSI Measurements and Mobility	2	
	Subtotal	2,583	= 30 kbps
	50% Overhead Factor		15 kbps
	Subtotal		= 45 kbps
	Maximum High Rate EI (Spectrophotometer		45 kbps
	Maximum Sampled Data Rate		= 90 kbps

The total sampled data rate for the Dedicated 7-Day Laboratory, as summarized in Table 3-2 by equipment unit, is 2,583 megabits per day, most of which results from several high-rate equipment items operating continuously. Thus, this total rate could be averaged to yield a meaningful value, which is approximately 30 kbps. This value was used as a basis for comparison between the rate required by the Life Sciences Laboratory and that provided by the sortie module. Adding an estimated 50 percent overhead factor, which is necessary to account for scheduling loss and transmission of non-data information of a management nature, results in a background sampled data rate of 45 kbps.

Superimposed upon this background rate will be short periods of high data transmission when particularly high rate devices are being used. This data is all of relatively short duration and can be scheduled not to occur simultaneously. The highest rate identified is 45 kbps from the spectrophotometer, which is operating an average of 9 minutes per day. Adding this value to the background rate yields a maximum instantaneous laboratory rate of 90 kbps. This is below the 100 kbps sortie capability and could be further reduced, if required, by hardwire connections of several equipment items to the recorders, and possibly by reducing the number of high rate devices used in the laboratory.

All communications to and from ground are via the shuttle orbiter communications system. In comparing the data down-link requirements to the shuttle capacity, it was assumed that 10 percent of the 7-Day Dedicated Laboratory average data rate of 45 kbps would require transmission to ground, or 4.5 kbps. Since the shuttle can only transmit about 9 percent of the time (100 n.mi. orbit assumed), the resulting down-link rate is 50 kbps. This value compares to a 25-256 kbps shuttle down-link availability to the sortie module payload, depending upon how much shuttle data is being down-linked simultaneously (the amount of which is unknown at present). However, the kbps requirement indicates a general compatibility with the shuttle communications capability.

The Life Sciences Laboratories generate video data, which will require a DMS video recording capability. In order to estimate this capability, an analytical model representing the video data acquisition was formulated. It was based upon the stated desires of the scientific investigators involved in the Task A and B effort. The number of video cameras assumed in each laboratory and their use makes up this model. Each laboratory was assumed to contain two cameras devoted to event monitoring. These cameras could be used, for example, to monitor Biomedicine, MSI, or LSPS experiment phenomena. The total use is shown in Table 3-3.

A second type of video coverage was designated short duration and was used, for example, to monitor crew habitability studies, the coverage of which is required only aboard the Dedicated 30-Day Laboratory. Four cameras were assumed for this coverage. The third type of video coverage results in the largest requirement for recording capacity and is the time-lapse coverage. It is used to monitor the biological

organisms on a 24-hour time-lapse basis. The model used assumed that one frame (picture) would be taken by each time-lapse camera every 10 seconds. The number of cameras devoted to this mode were four aboard the Shared 7-Day Laboratory and eight aboard the Dedicated Laboratories.

Table 3-3. Summary of Life Sciences Laboratory Video Camera Modes of Operation and Periods of Operation

Event Monitoring:	Biomedical/MSI/LSS Experiments	30 min/day
	Small Vertebrate Experiments	30 min/day
	Primate Experiments	60 min/day (Dedicated Labs only)
	Total	120 min/day (Dedicated Labs) 60 min/day (Shared Lab)
Short Duration Video:	10 seconds/15 minutes, 24-hour basis (30-Day Lab only)	
Time Lapse Video:	1 frame/10 seconds, 24-hour basis (e.g., 1 frame per 80 seconds for each rat within a cage module)	

The total number of tape recorders required to support Life Sciences research was determined for each of the laboratories. This quantity was based on the video model described above and the sampled and analog data generated by other research equipment. The three different types of recorders available for use aboard the baseline sortie were described by NASA as (1) a large-volume tape recorder, (2) a medium-capacity recorder, and (3) a video recorder. The laboratory requirements were compared with the characteristics of each of these recorders to obtain the number of each required aboard the Life Sciences Laboratories. The Shared 7-Day Laboratory data recording requirements can be satisfied with the existing three recorders. However, the Dedicated 7-Day Laboratory requires one additional recorder of each type, and the Dedicated 30-Day Laboratory requires two additional large-capacity recorders and one additional video recorder. The extra real-time video recorders were added to provide simultaneous coverage of experiment phenomena by two cameras, which is needed, for example, to cover the field of view for primate observations. The other recorders are for time lapse and sampled data, and are needed generally to provide continuous recording of data during the 12 hour off-duty period when no payload specialists are in the laboratories.

The additional DMS recording requirements outlined above are reflected in additional weight, power, and volume of recorders, as well as magnetic tape required to satisfy the dedicated Life Sciences Laboratories. In addition, TV transmission to ground is desired by the scientists and results in added communications equipment to be placed aboard all the laboratories.

Table 3-4. Electrical Power System Requirements for the Life Sciences Laboratories

	Shared 7-Day Lab	Dedicated Labs 7-Day	Dedicated Labs 30-Day
Average Power Use			
Research Equipment (kW)	1.13	1.59	1.90
Organism EC/LSS and DMS (kW)	0.20	0.59	0.67
Totals	1.33	2.18	2.57
Total Energy Consumption (kW-hr)	208	340	1,850
Total Energy Available on Sortie Module (kW-hr)	75 (Assumed)	150	150
Extra Energy Required (kW-hr)	133	190	1,700
Extra Fuel (H_2 and O_2) Required (kg)	58	82	729
Extra Tanks Required (Apollo Tanks):			
For H_2			
Number	1	1	7
Tank + H_2 Weight (kg)	39	43	311
Tank Envelope Volume (m^3)	0.44	0.44	3.09
For O_2			
Number	1	1	5
Tank + O_2 Weight (kg)	91	112	844
Tank Envelope Volume (m^3)	0.34	0.34	1.70
Total Tankage and Fluid Weight - kg (lb)	130 (286)	155 (341)	1,155 (2,540)

3.3 ELECTRICAL POWER SUBSYSTEM

Table 3-4 summarizes the requirements imposed upon the sortie module in the area of electrical power for each of the three Life Sciences Laboratories. The upper part shows the power and energy usage of the laboratories, and the lower part indicates the additional fuel and tankage required to meet these usage requirements.

Average power usage is broken down into that required for the research equipment and that required for the organism ECS and DMS subsystems. The total average power requirements range from 1.33 to 2.57 kW and are well under the average sortie module fuel cell capability of 4-5 kW.

The sortie module, however, carries only enough fuel to provide experiments with 150 kW-hr of total energy. Converting the laboratory average power requirements to energy, and using 6 1/2 days on-orbit time for the 7-day missions, we obtain a range of 208 to 1850 kW-hr for comparison. The difference between these requirements and the sortie

module energy provided is indicated in the table. For the Shared 7-Day Laboratory, only one-half of the 150 kW-hr has been assumed to be available for Life Sciences research, the remaining being used by the sharing FPE.

To provide for the extra energy requirements, extra H_2 and O_2 fuel and tankage were added to the sortie module. It was based on NASA guidelines regarding specific fuel consumption and Apollo tankage properties, and tankage weight and volume penalties were not prorated. One extra O_2 and one extra H_2 tank are required for the 7-Day missions. Seven H_2 tanks and 5 O_2 tanks are required for the 30-day mission.

3.4 THERMAL CONTROL SUBSYSTEM

The sortie module heat rejection subsystem uses Freon-21 externally in a space radiator to reject heat from an internal water cooling loop. The water would be available for cold plating Life Sciences equipment within the module. Alternatively, this equipment could reject heat to the sorite module cabin air. The heat rejection capability of the sortie module is specified to correspond to the average power available to experiments which is 4-5 kW.

The average heat loads of the Life Sciences Laboratories are shwon in Table 3-5, and result primarily from the electrical power consumption of the various research equipments. The heat loads are lower than the sortie module capability and therefore do not require any supplementary heat rejection equipment chargeable to the Life Sciences Laboratories. In the case of the Shared 7-Day Laboratory, one-half of the sortie module capacity was assumed to be available to Life Sciences, the remaining half to be used by the sharing payload.

Table 3-5. Summary of Life Sciences Heat Loads

	Shared 7-Day Lab	Dedicated 7-Day Lab	Dedicated 30-Day Lab
Life Sciences Laboratory Heat Loads			
Electrical Equipment, kW	1.33	2.18	2.57
Organism Metabolic Loads, kW_t	0.04	0.10	0.10
Totals	1.37	2.28	2.67
Sortie Module Heat Rejection Capability (Final Guideline), kW_t	2-2.5 (1/2 assumed)	4-5	4-5
Extra Heat Rejection Equipment Required	None	None	None

Although the Life Sciences Laboratories do not require extra cooling capacity, they do require low temperature coolant at about 283°K (50°F) for the condensers within the organism ECS loops. This an area where design integration between the Life Sciences and equipment and the sortie mo ule heat rejection subsystem will be required.

3.5 CREW EC/LSS SUBSYSTEM

The shuttle orbiter/sortie module provides crew EC/LSS equipment and consumables for a total of four crewmen for seven days. These four are comprised of two shuttle-devoted crewmen, one mission specialist, and one payload specialist. The mission specialist performs general maintenance and subsystems tasks aboard the sortie module. He is available for Life Sciences operations only on a limited basis. The payload specialist is devoted entirely to Life Sciences Laboratory tasks. Any additional payload specialists or any extension in mission duration beyond seven days is chargeable to the Life Sciences payload.

The Shared 7-Day Laboratory requires only one payload specialist and therefore no extra equipment. However, the Dedicated 7-Day and 30-Day Laboratories do require extra equipment. For these laboratories, three (two extra) payload specialists are required, and additional fixed equipment for the extra two men is chargeable to the Life Sciences Laboratories; see Table 3-6. This equipment includes seats, restraints, personal gear, and emergency equipment. Also, since the shuttle provides only consumables for one payload specialist for seven days, additional consumables such as oxygen, LiOH, utensils, food, and clothing are chargeable to the Life Sciences Laboratories. For the Dedicated 7-Day Laboratory, the quantity required is for two men for seven days; and for the Dedicated 30-Day Laboratory, the quantity is for two men for 30 days, plus four men for 23 days.

3.6 SUMMARY OF SUPPORTING SUBSYSTEM WEIGHT, POWER, & VOLUME

Table 3-7 is a summary of the weight, power, and volume of the extra subsystem requirements necessary to support the Life Sciences Laboratories (in addition to the sortie module and shuttle baseline subsystems). The subsystems listed in the table have been discussed in the preceding sections. All subsystems will require extra equipment except the TCS. The largest weight requirements are for the 30-day mission for DMS recording tape, fuel for the EPS, and consumables for the crew EC/LSS. The average power requirements of the extra subsystem equipment are quite low. An allowance of 10 percent was added to all subsystem weights and volumes to account for supporting structure.

Table 3-6. Crew EC/LSS Equipment Required to Support the Life Sciences Laboratories

Equipment	Weight, kg (lb) Dedicated 7-Day Laboratory	Dedicated 30-Day Laboratory
Fixed Equipment for One Extra Man		
Seats and Restraints	54	
Personal Equipment	14	
Emergency Equipment	24	
Weight of Crewman	162	
Miscellaneous	28	
Fixed Equipment Subtotal	282 (620)	
Consumables	Basis	
	2 Men, 7 Days (14 m-d)	2 Men, 30 Days + 4 Men, 23 Days (152 m-d)
Oxygen + LiOH Canisters	36	405
Food	18	187
Utensils	8	98
Clothing	8	75
Consumable Subtotal	70 (154)	765 (1680)
Total Fixed Equipment + Consumables	352 (774)	1047 (2300)

Table 3-7. Summary of Supporting Subsystem Weight, Power and Volume

Subsystems and Supporting Equipment	Shared 7-Day Laboratory Wt (kg)	Avg Power (W)	Vol (dm^3)	Dedicated 7-Day Laboratory Wt (kg)	Avg Power (W)	Vol (dm^3)	Dedicated 30-Day Laboratory Wt (kg)	Avg Power (W)	Vol (kg)
Organism ECS	70	170	154	142	390	381	280	390	553
DMS Hardware & Tape	171	29	169	397	199	449	1252	279	1352
EPS Fuel & Tankage	130	0	0*	155	0	0*	1155	0	0*
Thermal Control	0	0	0	0	0	0	0	0	0
Crew EC/LSS Equipment	0	0	0	352	TBD	0*	1047	TBD	0*
Supporting Structure (10%) of Subsystem Equipment	37	0	32	105	0	83	373	0	191
Total	408	199	355 (12.5 ft^3)	1151	589	913 (32.3 ft^3)	4107	669	2096 (74.1 ft^3)

*Assumed to be outside the sortie module.

SECTION 4

SORTIE MODULE/LIFE SCIENCES LABORATORY LAYOUTS AND SUMMARY

4.1 LIFE SCIENCES LABORATORY LAYOUTS

Having established the properties of both the research and supporting subsystem equipment for the Life Science's Laboratories, preliminary layouts were developed for each laboratory. These layouts were based on the sortie module configuration containing a single floor running longitudinally in a 4.76 m (14 ft) diameter by 7.32 m (24 ft) long sortie module.

The Shared 7-Day layout is shown in Figure 4-1. The Life Science's equipment is located generally in the right end of the sorite module above the single floor (as drawn in Figure 4-1). The Life Sciences equipment occupies approximately one-half the length of the sortie module above the floor. The resulting envelope volume is approximately 31.8m^3 (1300 ft^3). In the left end of the module and also below the floor is subsystem equipment standard to all sortie modules. This equipment includes the DMS crew station console and electronics, crew systems equipment, crew EC/LSS equipment, and EPS equipment. The total internal volume of the sortie module is approximately 87.8m^3 (3100 ft^3). Subtracting the 31.8m^3 envelope volume of the shared 7-Day Laboratory leaves 51m^3 (1800 ft^3) for the standard sortie module subsystems and the sharing payload equipment.

A summary of these envelope volumes for all the Life Science's Laboratories is given in Table 4-1. In this table, the laboratory envelope volume is the total envelope around the Life Sciences equipment, excluding the baseline sortie module equipment. This envelope includes aisle-ways, access space, and crew operation space. Thus, it is much more than the actual research equipment volume contained within it. This equipment volume is listed in brackets in the table. The difference between the total sortie module internal volume and the laboratory envelope volume is that available for the baseline (standard) sortie module subsystems, and, in the case of the Shared 7-Day Laboratory, for the payload sharing the sortie module with Life Sciences.

The layout of the Dedicated 7-Day Laboratory is shown in Figure 4-2. It occupies all of the volume above the floor of the sortie module except for the left end, as depicted where the standard DMS equipment is located. The laboratory contains 11 racks and consoles. Ten are for research equipment and one is for DMS recorders and tape storage. Organism holding facilities include six cage modules and two small primate cylinders. The other major items are the laminar flow bench, which can interface with the holding units; the bicycle ergometer; rotating litter chair; teleoperator control console; and body mass measurement device. Many of these devices are

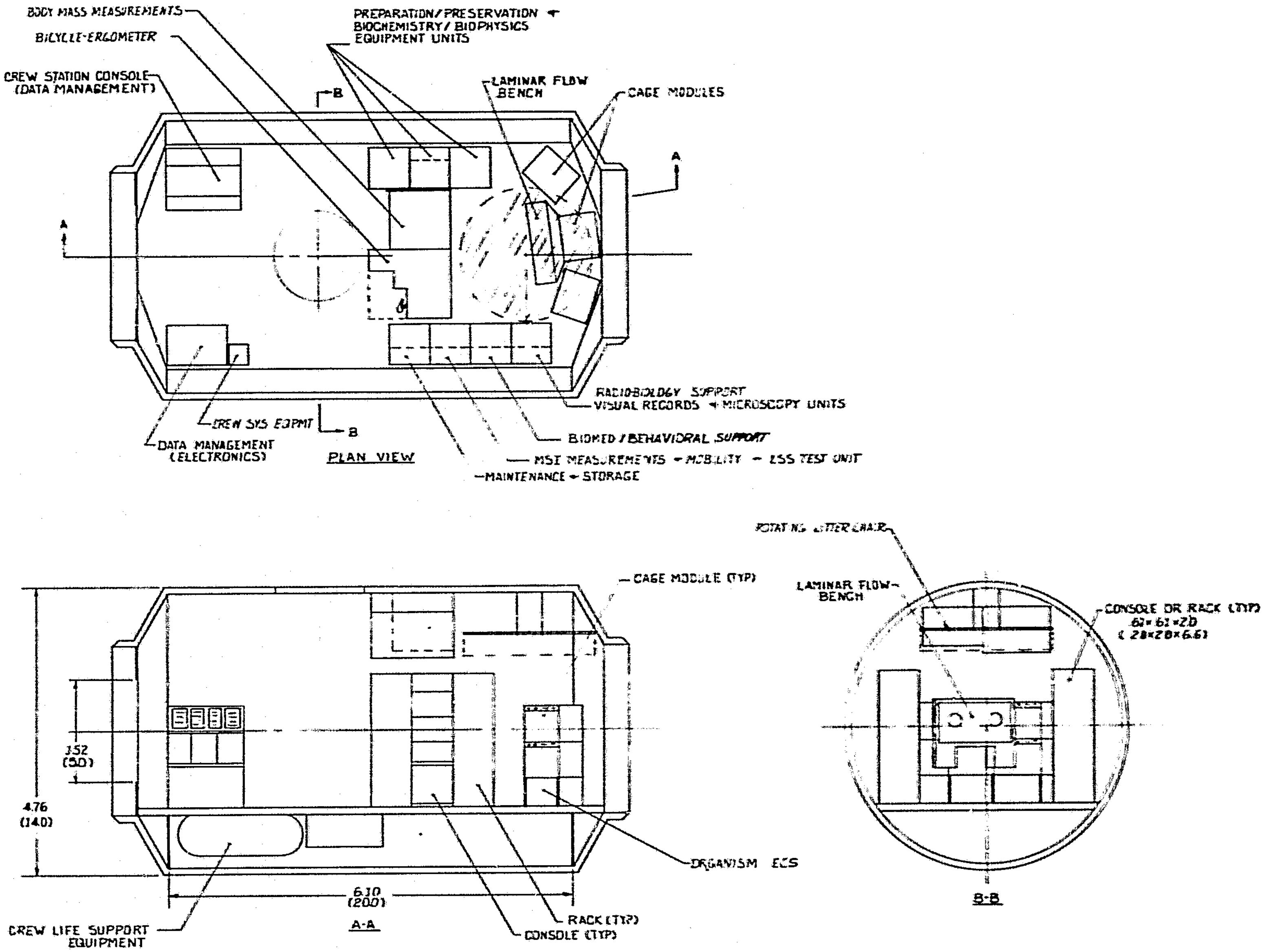


Figure 4-1. Equipment Layout in Shared 7-Day Laboratory

Table 4-1. Summary of Life Sciences Laboratory/Sortie Module Envelope Volumes

Volumes	Shared 7-Day Laboratory	Dedicated 7-Day Laboratory	Dedicated 30-Day Laboratory
Total Internal Volume of Sortie Module m^3 (ft^3)	87.8 (3100)	87.8 (3100)	87.8 (3100
Laboratory Envelope Volume, m^3 (ft^3) (Includes Research Equipment, Add-On Subsystems, Equipment, Aisles, Access Space, Etc.)	36.8 (1300)	59.5 (2100)	59.5 (2100)
[Research Plus Subsystem Equipment Volume within Laboratory Envelope Volume, m^3/(ft^3)]	[12.5 (442)]	[17.6 (622)]	[20.6 (728)]
Remaining Internal Volume, m^3 (ft^3) (For Standard Sortie Module Subsystems Structure, Sharing Payload, Etc.)	51.0 (1800)	28.3 (1000)	28.3 (1000)

exemplary in nature. That is, since it is not definitely known what devices will be used in future Biomedical/MSI experiments, devices such as the rotating litter chair and bicycle ergometer have been included to be representative of the type of future equipment to be used. The Dedicated 30-Day Laboratory layout is shown in Figure 4-3 and is quite similar to the Dedicated 7-Day Laboratory. The addition of one rack and one console brings the total number of racks and consoles to 13, and requires a slightly more compact arrangement of items within the laboratory. The volumes of both the dedicated laboratories is summarized in Table 4-1.

An internal configuration for the sortie module which is designated as having Z floors is still being considered by NASA. As shown in Figure 4-4 it has two general floor levels rather than one, with a step in the upper level. In order to determine what impact the Z floors would have on the Life Sciences Laboratories, the Dedicated 30-Day Laboratory equipment was placed in this configuration. This laboratory contains the most equipment and was therefore used to indicate generally whether all the Life Sciences Laboratories would fit into the Z floors module. The Z floors laboratory shown in the figure contains both baseline sortie moudle subsystem equipment and Life Sciences research equipment. Since the floor-to-ceiling height is approximately 1.7m (5-1/2 ft), the standard racks and consoles used to contain the Life Sciences equipment were reduced from 2 m (6.6 ft) to 1.5m (5 ft). Thus, additional racks and consoles had to be added to make up for the lost volume. This resulted in 17 racks and consoles compared with 13 used previously. The remaining equipment is identical to that contained in the single-floor version of the Dedicated 30-Day Laboratory.

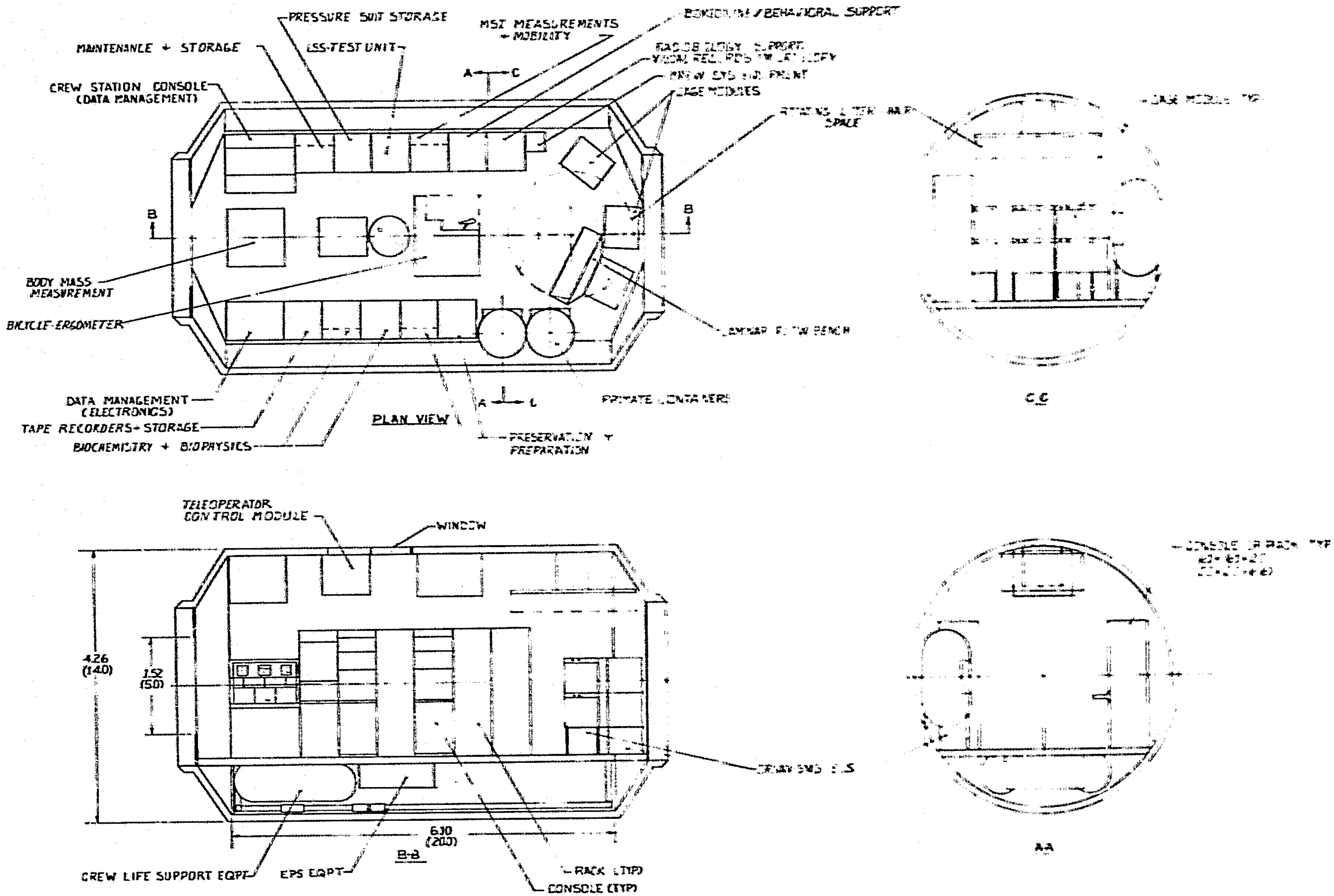


Figure 4-2. Life Sciences Equipment Layout in Dedicated 7-Day Laboratory

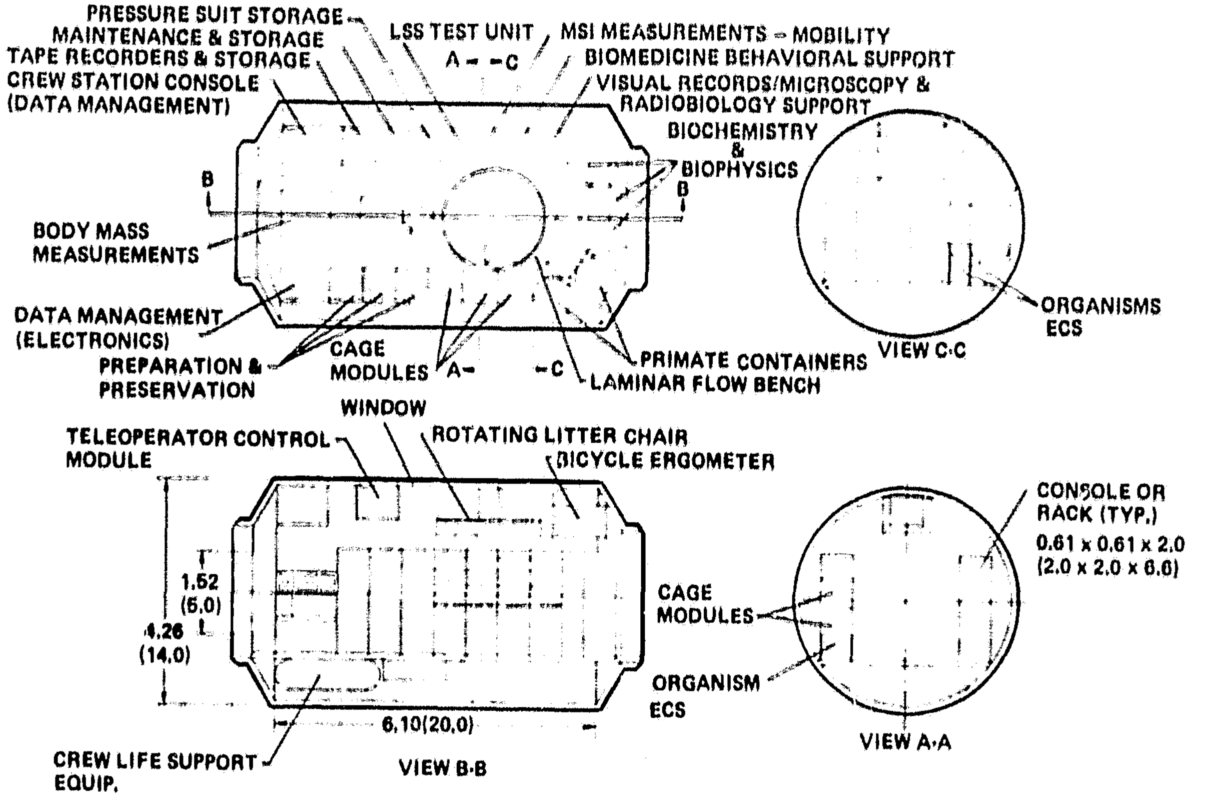


Figure 4-3. Equipment Layout in Dedicated 30-Day Laboratory

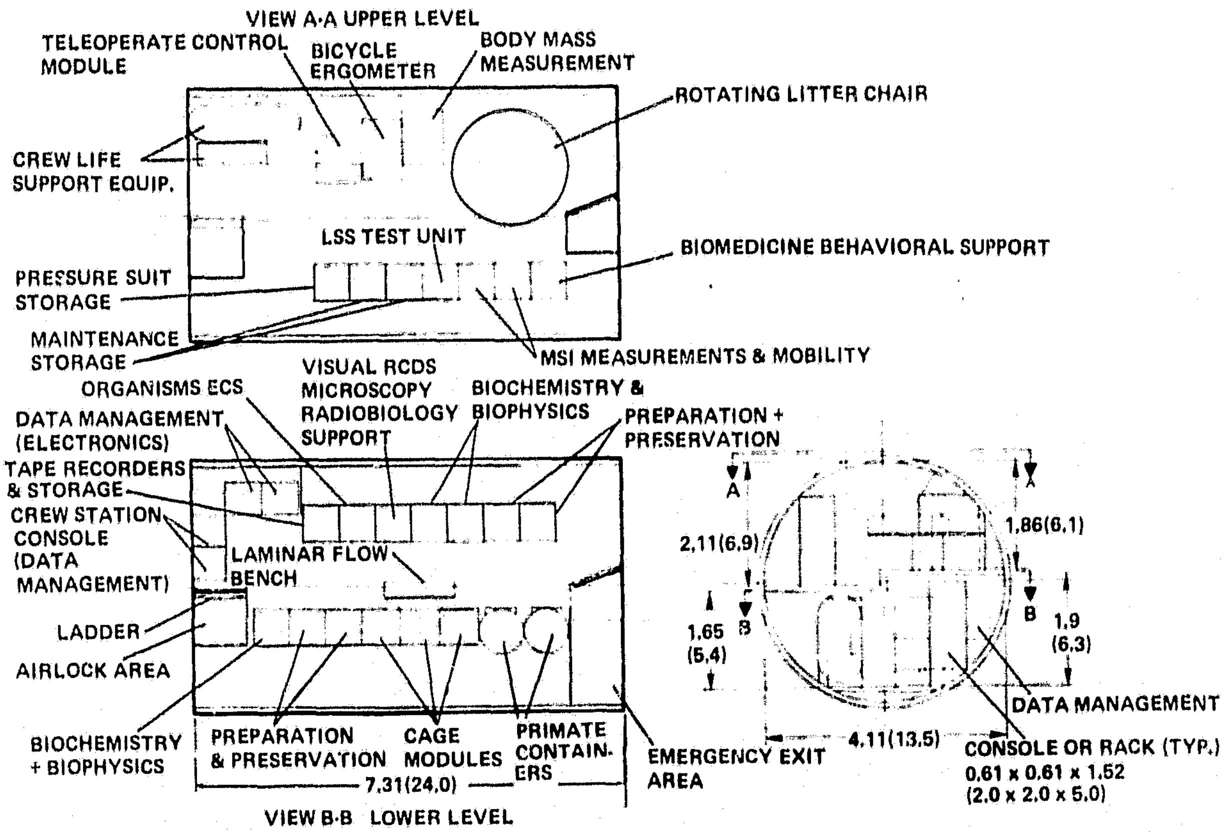


Figure 4-4. Dedicated 30-Day Laboratory Layout in Sortie Module with Z Floors

All of the single-floor laboratories require the placement of Biomedical/Behavioral research specific equipment on the upper wall of sortie module as depicted in Figures 4-1 to 4-3 (on the ceiling). This action was necessary to get all the equipment into the sortie module, but does not adhere to the ideal case where all equipment is placed so that the crew assumes a common (heads-up) orientation. With the Z floors configuration, however, this equipment, which includes the bicyble ergometer, rotating litter chair, body mass measurement device, and teleoperator control console, can be oriented normally rather than upside down relative to the normal crew activity orientation.

4.2 LIFE SCIENCES/SORTIE MODULE INTEGRATION SUMMARY

Table 4-2 was prepared to summarize the general requirements of the Life Sciences Laboratories and compare them to the shuttle/sortie modules capability to meet these requirements. The shuttle has payload capability of 14,500 kg (32,000 lbs.). Subtracting the 9,100 kg (20,000 lbs.) baseline sortie module design weight, leaves 5,450 kg (12,000 lbs.) for the Life Sciences Laboratories. As shown in the table, the Dedicated 30-Day Laboratory exceeds this weight capability. This problem area was found to exist late in the study due to a decrease in shuttle/sortie module weight capability guideline being used. Its resolution will require reduction of research capability or an increase in weight capability assignable to the experimental laboratory equipment.

Most of the other properties included in Table 4-2 have been previously discussed in Sections 2.0 and 3.0. The sortie module capability is generally sufficient to meet the Life Sciences requirements, or can be brought to a sufficiency level by adding equipment which has been charged to Life Sciences and included in the weight volume and power values for the laboratories.

Table 4-2. Summary of Life Sciences Laboratory/Sortie Module Integration Parameters

Parameter	Available in Sortie Module	Life Sciences Payload Requirements: Shared Lab	Dedicated 7-Day Lab	Dedicated 30-Day Lab
Weight, kg				
Research Equipment + Supporting Rack and Consoles		2184	3300	4084
(Subsystems Equipment)				
Organism ECS		70	142	280
DMS Hardware & Research Recording Tape		171	397	1252
EPS Fuel & Tankage		130	155	1155
Thermal Control Subsystem		0	0	0
Crew EC/LSS		0	352	1047
Supporting Structure for Subsystem		37	105	373
Subsystem Subtotals		408	1151	4107
Total Weight, kg (lb)	5450 (12,000)	2592 (5702)	4451 (9792)	8191 (18,020)
Average Electrical Power, kW				
Research Equipment		1.13	1.59	1.90
Subsystem Equipment		0.20	0.59	0.67
Total	4 to 5	1.33	2.18	2.57
Electrical Energy, kW-hr	150	208	340	1850
Heat Rejection, kW_t	4 to 5	1.37	2.28	2.67
Sampled Data Acquisition Rate, kbps	100	<45	45	≈45
Sampled Data Donwlink Rate, kbps	25-256	<50	50	≈50
Payload Specialists	2-4	1	3	3

SECTION 5

CARRY-ON PAYLOADS

The current study included not only the definition and integration of the larger sortie module laboratories but also the definition of smaller, portable, primarily self-contained laboratories that could be placed in the multipurpose sortie lab or the crew compartment of the shuttle orbiter. These carry-on laboratories were included in the current phase of the study; however, they did not receive the Task A & B analyses. Consequently, they have not been defined at the same detail level as the larger laboratories.

5.1 CONCEPTUAL DESIGN APPROACH

The study overview, Figure 5-1, indicates the major elements of the conceptual design task. It is based on NASA guidelines consisting of:

a. The research areas of primary interest.

b. A set of requirements.

c. A set of tentative constraints (Figure 5-2).

A design analysis reviewed the functional capabilities desired for each Carry-On Laboratory and identified the equipment needed to provide that capability. This selection process was guided by the NASA requirement to minimize the data analysis work in space, emphasizing sample return for ground analysis. The configuration definition phase was guided by the NASA requirements for (1) modular design to ease removal and replacement of components and (2) maximum equipment commonality within and between FPEs. The requirement for isolated test environments to prevent cross-contamination in biology and biomedicine was also adhered to as well as the desire to use off-the-shelf equipment wherever possible. This task resulted in the conceptual design of five laboratories: two in biology and one each in biomedicine, man-systems integration, and life support systems.

5.2 EXAMPLE CARRY-ON LABORATORY CONCEPT

Figure 5-3 illustrates the conceptual design of the Biology and Biomedicine Carry-On Laboratory, including the dimensional envelope and functional relationship between the Holding Unit Moduel (HUM) and the Bioresearch Support Module (BRSM).

The HUM is designed to accommodate FPE-specific kits. For the biological FPEs, these would contain the living organisms on which a variety of experiments would be performed. For the biomedical FPEs, additional instrumentation for obtaining

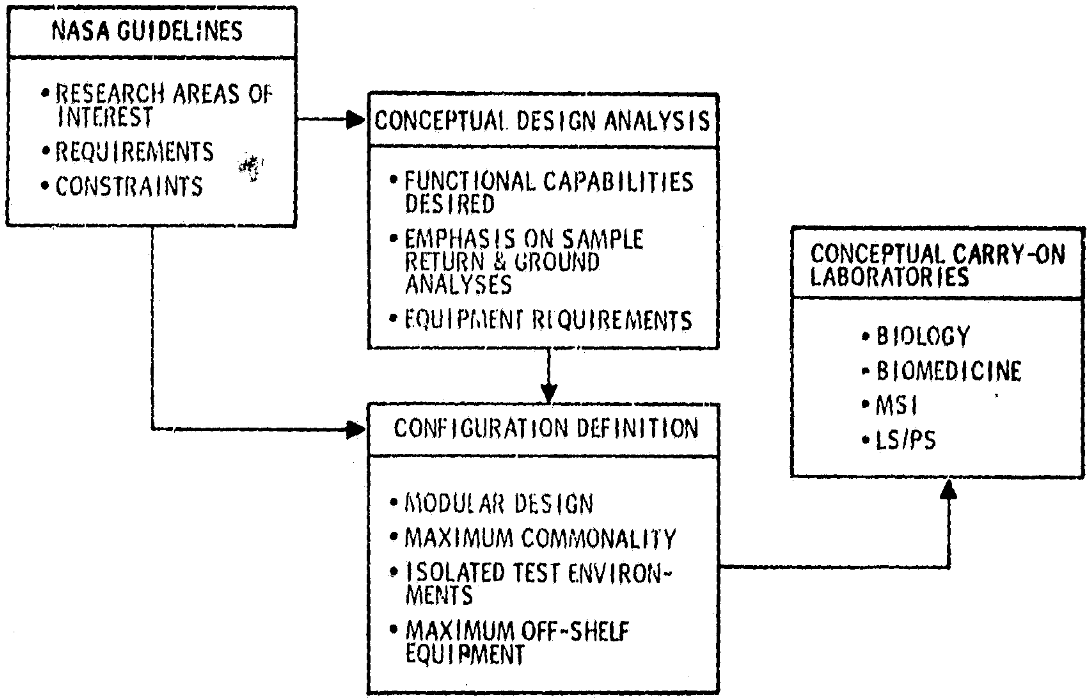


Figure 5-1. Carry-On Laboratory Concepts - Overview

WEIGHT	136 kg (300 LB.)
POWER REQUIREMENTS	
SUSTAINED	100 WATTS
PEAK	500 WATTS
VOLUME	.85 m^3 (30 $FT.^3$)
MAXIMUM PACKAGE DIMENSIONS	0.61 m x 0.76 m x 0.91 m (2 FT. x 2.5 FT. x 3 FT.)
PACKING DENSITY	
MAXIMUM	320 kg/m^3 (20 LB./$FT.^3$)
AVERAGE	160 kg/m^3 (10 LB./$FT.^3$)
CREW TIME	1 HR./DAY

Figure 5-2. Carry-On Laboratory Constraints

biomedical measurements on man would be included. The HUM also contains some of the common-use and experiment-specific equipment and interfaces with a collapsible glove box to minimize contamination of the crew compartment and the experiments.

The Bioresearch Support Module contains the majority of the equipment required to collect and preserve the test specimens and experimental data.

5.3 CARRY-ON CONCEPT SUMMARY

Figure 5-4 shows the results of the design concept study with respect to the major constraints defined in Figure 5-2. In most cases, these characteristics are within the tentative constraints set by NASA. The volumes are less than the 0.85 m^3 (30 ft^3) constraint. The peak powers, with the exception of life support and protective systems and probably the plant research laboratory, are close to the 500-watt constraint. The heaviest laboratory is approximately 159 kg (350 lb). This does not appear to be a major problem. Although not considered during the design concept activity, the plant and invertebrate research laboratories probably fall very close to the tentative constraints.

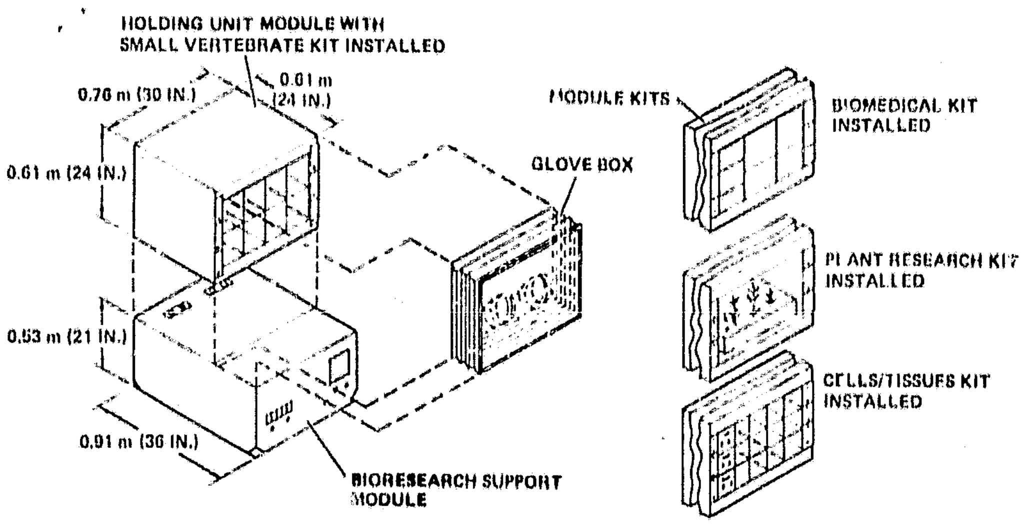


Figure 5-3. Conceptual Carry-On Laboratory - Biology & Biomedicine

FPE	NO. OF PACKAGES	WEIGHT kg (LB.)	POWER (WATTS)	VOLUME m^3 CU. FT.
MEDICAL RESEARCH	2	152 (334)	400	0.566 (20)
VERTEBRATE RESEARCH	2	150 (332)	462	0.555 (19.6)
CELLS & TISSUES RESEARCH	2	142 (314)	565	0.637 (22.5)
PLANT RESEARCH	TBD	TBD	TBD	TBD
INVERTEBRATE RESEARCH	TBD	TBD	TBD	TBD
LIFE SUPPORT & PROTECTIVE SYSTEMS	2	159 (350)	725	0.637 (22.5)
MAN-SYSTEM INTEGRATION	2	136 (300)	433	0.557 (19.7)

Figure 5-4. Carry-On Laboratory Data Summary

SECTION 6

PRELIMINARY PROGRAM PLANS

6.1 MISSION AND LABORATORY DEVELOPMENT MODEL

The proposed flight program schedule is a significant guideline to the future planning activity in Life Sciences. The typical mission model shown in Figure 6-1 appears to be within the area of present NASA flight opportunity planning. To meet the flight opportunity dates, hardware development should be completed about two years before flight. The two year lead-time is required to permit principal investigators (PIs) to use the equipment during baseline ground control studies. In addition, this two year period is used for the physical integration of the equipment with the sortie module.

The typical laboratory development schedule, shown in the lower portion of Figure 6-1, summarizes the preliminary scheduling activity for the Life Sciences Laboratory. The commitment to procure the Life Sciences Laboratory equipment must be made considering the development time for the equipment as well as the PI and integration activity.

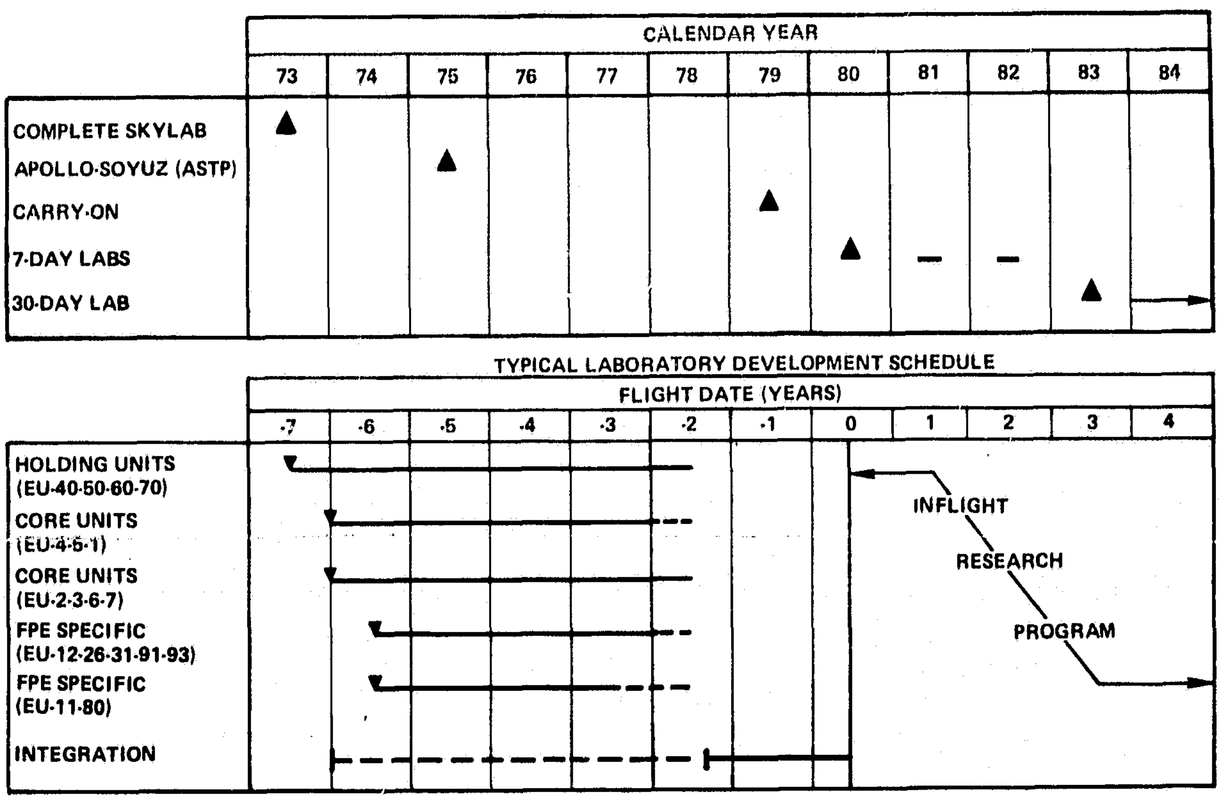


Figure 6-1. Life Sciences Laboratory Guideline Schedules — Typical Mission Model

6.2 LABORATORY DEVELOPMENT SCHEDULES

Laboratory development is paced by the development of the equipment units (EU) within each laboratory, which in turn is paced by the development of each equipment item (EI) within each EU. The development time estimate for each EI has been based on the complexity of the EU and the difficulty of its manufacture. The development time for each EU was assumed to be the same as the longest development time of any of its component EIs.

To use the same assumption at the payload level — that is, payload development time would be the same as the longest EU development time — is not acceptable for several reasons. First, it is desirable to minimize annual funding peaks. Assuming that all EUs will be developed within the development time span of the longest EU would create unnecessarily high funding peaks that are reduced by a staggered development schedule. Secondly, it is desirable to initiate development of the more complex EUs first to provide time for solving unanticipated technical problems without impacting the laboratory development schedule.

To define an appropriate development schedule, it was necessary to establish EU development priorities. These priorities are based on the following assumptions:

a. EUs containing high development risk (pacing) equipment will be initiated at an early date (e.g., holding units). Pacing equipment are those items that closely interface with, and are configuration drivers for, a number of other equipment items.

b. Common use (CORE) EUs have a high development priority with the exception of the maintenance and storage units.

c. Support EUs will be initiated only after their key EUs are well defined. The key EUs are the basic holding and FPE measurement units.

d. EUs whose configuration might be altered by the Skylab experimental results will be delayed until those results have received sufficient analysis to indicate configuration impact.

A representative equipment unit development schedule based on the foregoing assumptions is illustrated in Figure 6-2. This schedule is compatible with the general mission model shown in Figure 6-1.

6.3 LABORATORY COSTING ANALYSIS

An overview of the cost analysis approach used during the study is illustrated in Figure 6-3. The equipment cost estimates and laboratory funding schedules are based on the cost estimates developed during Tasks A & B. These estimates were based on quotes

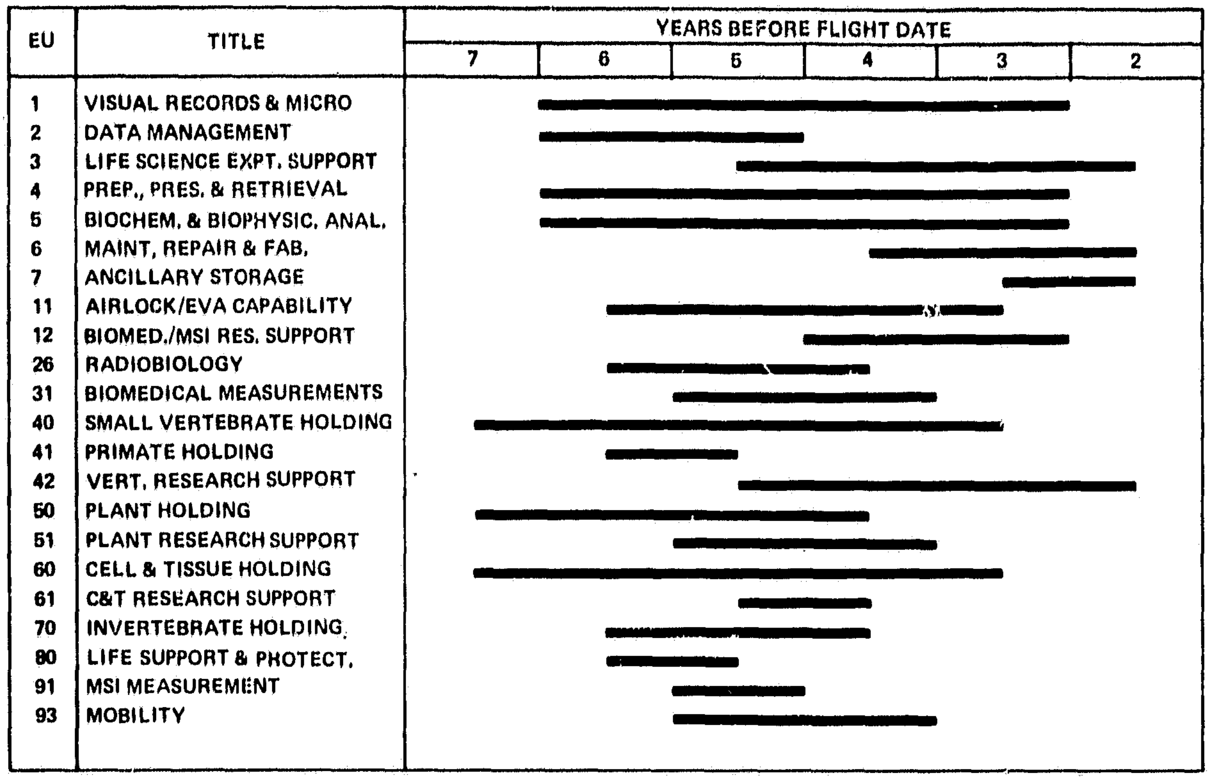


Figure 6-2. Sample EU Development Schedule — 7-Day Laboratory

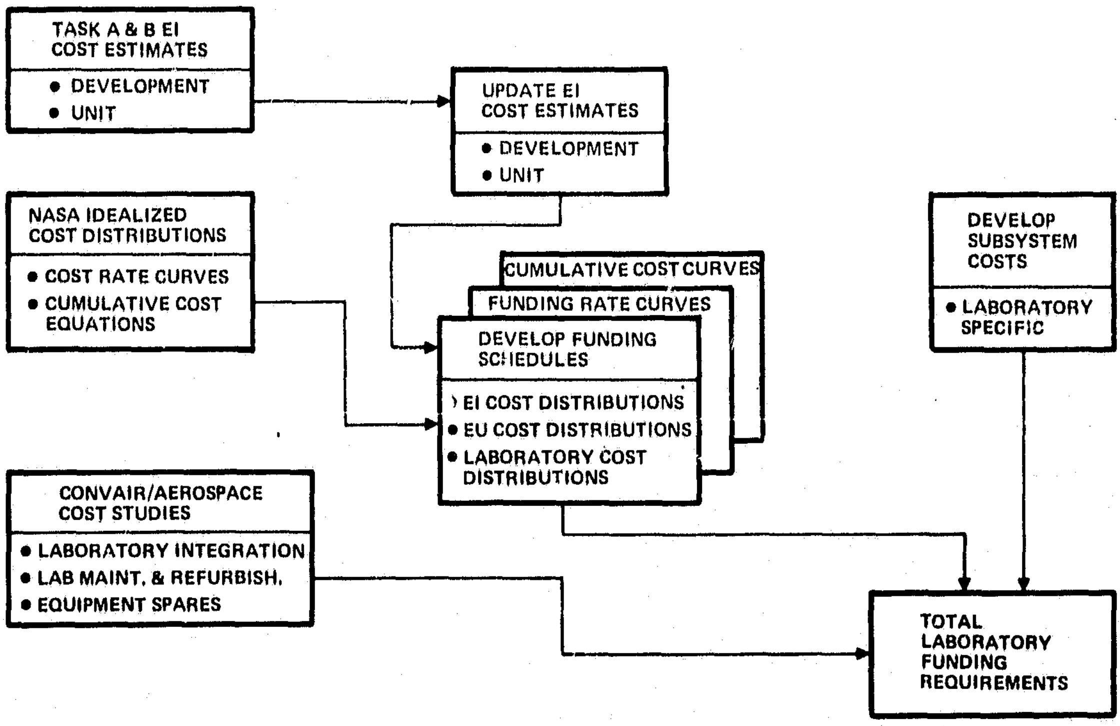
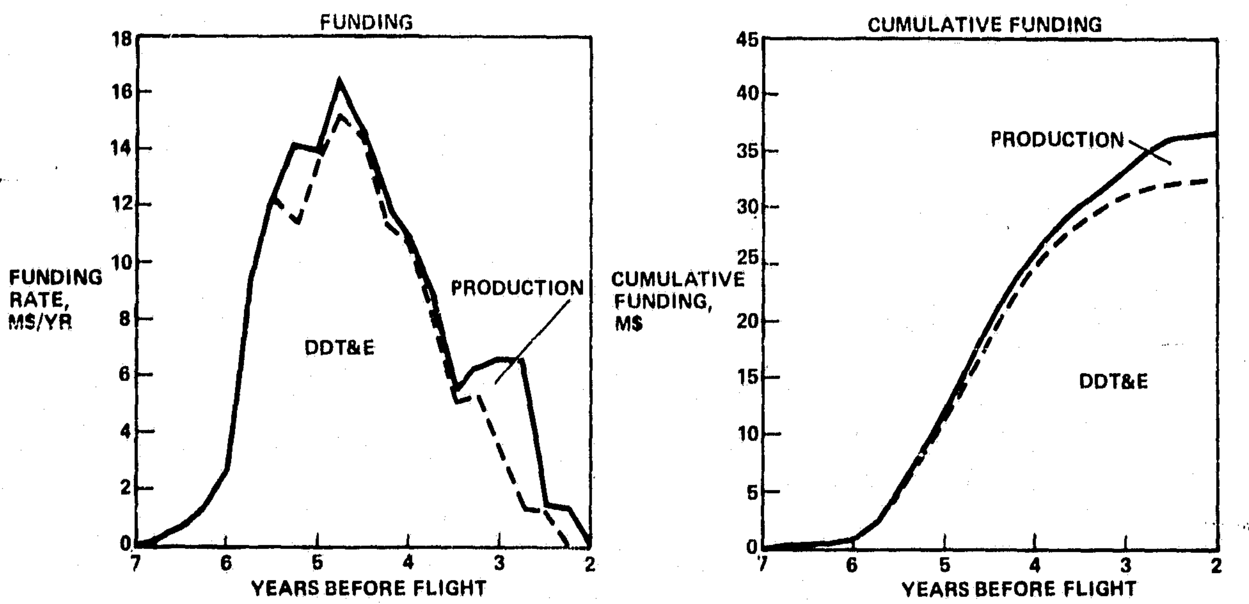


Figure 6-3. Cost Analysis Overview

from manufacturers; and suppliers, commercial catalog listings and in-house sources. The technical and costing specialist were guided in their estimates by NASA specifications, which require extensive analysis and testing prior to flight. These estimates were updated during this portion of the study, and cost distribution curves were calculated for each equipment item, equipment unit, and laboratory based on the idealized NASA planning guide cost distribution curves. Laboratory-specific subsystem costs were estimated; and laboratory integration, maintenance/refurbishment and equipment spares costs were estimated using previously developed cost methodology. The sum of these three major elements was the total laboratory funding requirements.

6.3.1 COST ESTIMATING APPROACH. The equipment item (EI) cost estimating activity used as a typical guide the NASA specifications for flight experimental hardware. An example of these specifications is the Experiment General Specification for Hardware Development issued by the Office of Manned Space Flight for the Apollo Applications Program in 1969. Its purpose is to provide guidelines for the development of experiment hardware at minimum cost within the constraints of crew safety and mission success. To estimate laboratory funding schedules, the cost distribution of each of the equipment items (EI) was estimated, followed by the equipment unit (EU) cost distributions, and finally the laboratory cost distributions. The cost model distribution used was based upon the NASA idealized cost distribution curves presented in NASA document DRD MF-030. Figure 6-4 is the resulting summation of all the EI and EU cost distributions used to estimate the cost of the Dedicated 30-Day Laboratory.



DEV	0.91	10.50	13.48	6.48	1.10
PROD	0.00	0.68	0.63	0.95	2.12
TOTAL	0.91	11.18	14.11	7.43	3.22

0.91	11.41	24.89	31.37	32.46
0.00	0.68	1.31	2.26	4.8
0.91	12.09	26.20	33.63	37.26

Figure 6-4. Sample Laboratory Cost Distribution Curves — Dedicated (30-Day) Laboratory

6.3.2 COST SUMMARY. Costs other than those for the research equipment were determined to estimate a total laboratory funding requirement. These costs are shown in Figure 6-5. They do not include the costs for the sortie module and baseline subsystems, launch operations, flight operations, ground support equipment, and ground-based mission support facilities. They do include the organism ECS costs, which are specific to the Life Sciences Laboratories, and the following costs, wheih were determined using methodology from previous experiment payload cost studies:

a. Laboratory Integration - Includes equipment interface hardware, integrated software, and integrated testing, and was estimated to be 50 percent of total equipment cost.

b. Laboratory Maintenance and Refurbishment - Estimated to be 50 percent of total equipment cost for a nominal 10 year program duration.

c. Equipment Spares - Estimated to be 200 percent of the equipment unit costs for a nominal 10 year program, based on 50 percent of unit cost for initial spares and 15 percent of unit cost per year thereafter.

The total funding required to develop each laboratory independently and use it for a nominal 10 year program is indicated. Since the more probable case will be evolutionary laboratory development, the following model was used as an example. The Shared 7-Day Laboratory is developed first and used early in the program, followed by the Dedicated 7-Day Laboratory, and finally the Dedicated 30-Day Laboratory. The indicated mission duration was assumed for each of the laboratories as well as a savings of approximately 50 percent in the cost of integration and spares for the two dedicated laboratories because of prior development on the preceding laboratory.

COST ELEMENT	LABORATORIES		
	SHARED (7-DAY)	DEDICATED (7-DAY)	DEDICATED (30-DAY)
RESEARCH EQUIPMENT:			
DEVELOPMENT	21.8	29.1	32.5
PRODUCTION	2.1	4.2	4.8
ORGANISM ECS	4.8	6.3	6.3
LABORATORY INTEGRATION	14.4	19.8	21.8
LAB MAINTENANCE & REFURBISHMENT	14.4	19.8	21.8
EQUIPMENT SPARES	4.2	8.4	9.6
INDEPENDENT LABORATORY DEVELOPMENT	61.7	87.6	96.8
BASED ON MISSION DURATION (YEARS)	1	2	7
EVOLUTIONARY LABORATORY DEVELOPMENT:			
Δ COSTS	45.9	27.4	36.4
CUM COSTS	45.9	73.3	109.7

Figure 6-5. Cost Summary (M$)

SECTION 7

CONCLUSIONS

The results of this study provide a firm basis for the planning of future Life Sciences space research.

First, the integration activity (Task C) has shown that the requirements for Life Sciences Laboratories are generally in line with the capabilities of the shuttle/sortie module concept. The second aspect of the study (preliminary costs and schedules) underlines the need for the timely consideration of proposed equipment development activities to meet the flight opportunities scheduled for the 1980s.

7.1 SUMMARY OF LABORATORY CHARACTERISTICS

The major characteristics of the three laboratories studied during Task C & D are summarized in Figure 7-1.

Scientific Laboratory	Total Weight (kg)	Average Power (kW)	Equipment Costs ($M)	Payload Specialist	Module Layout Requirement
Shared-7	2,592	1.33	61.7	1	1/2
Dedicated-7	4,451	2.18	87.6	3	1
Dedicated-30	8,191	2.57	96.8	3	1

Figure 7-1. Summary of Life Sciences Laboratory Characteristics

The total weight of the laboratories appears to be a problem for the Dedicated 30-Day concept only. Potential ways to resolve this problem include reduction in mission duration, reduction in functional capability, or relaxing the sortie module weight restriction.

The preliminary research equipment costs are in line with present NASA accepted experiment hardware development program costs. An evolutionary development of the three laboratories would result in costs considerably less than the sum of costs indicated for independent development. The example cost model in Section 6 for the orderly growth from the Shared 7-Day to the Dedicated 30-Day was approximately $110 million. Other characteristics, including power, crew size, and module layouts do not pose any significant problems to the development of the Life Sciences Laboratories.

7.2 SUPPORTING RESEARCH AND TECHNOLOGY

The areas of significant SRT that affect the development of a Life Sciences Laboratory are summarized in Figure 7-2. Probably the singlemost important SRT area is the organism holding units.

Area	Justification
Organism Holding Units	Required by all research organisms except man. Required for PI acceptance tests and ground controls.
Bioexperiment Support-Transfer	Dictates requirements for spacecraft interface and ancillary equipment
Organism ECS	Required for all Life Sciences Laboratory concepts.
Laminar Flow Bench	Required for organism handling and sampling. Significant interface with analysis EUs. Provides isolation between organism and crew.
Video Data Control Unit	Design concepts influence research protocols. Requirements interface with holding units and ancillary equipment.
Internal Centrifuge Definition Study	Design driver in determining laboratory size. Dictates ground support facility requirements. Establishes and influences research protocols

Figure 7-2. Supporting Research & Technology

The organism holding and ECS units provide specified environments for a broad range of biological organisms. This equipment must be designed to meet different experimenters' needs, while satisfying each experimenter's requirement to conduct scientifically valid research. These equipment units are required in all of the laboratory concepts evolved during this study, including the Carry-On Laboratory. Accordingly, the potential for continued and frequent use of these units is high.

The Laminar Flow Bench, Video Data Control Unit, and Internal Centrifuge must also be developed early in the program to support user acceptance tests, development of research protocols, and ground control studies. All SRT activities must be initiated at the earliest possible time to guide the selection of research objectives, facility development, and program planning to meet scheduled flight dates. Two examples of the SRT areas are shown in Figure 7-3.

The Bioexperiment Support and Transfer (BEST) unit, as sketched has been developed to the state of an operating engineering breadboard. The BEST unit has undergone initial PI use and evaluation at NASA/ARC and Concept Verification Test (CVT) at NASA/MSFC.

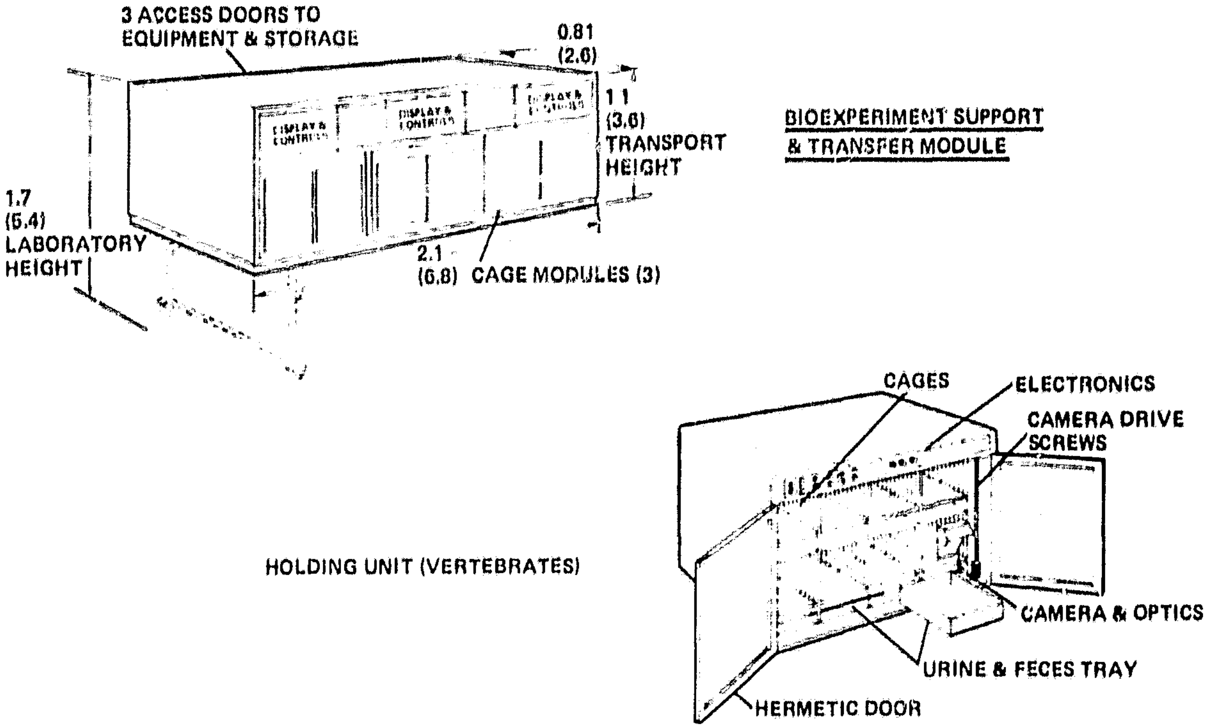


Figure 7-3. Bioexperiment Support & Transfer Unit & Organism Holding Unit

The holding units as shown can be configured to support all research organisms from cells and tissued to various vertebrates such as rats, mice, or quail. The holding unit, as indicated, becomes an integral part of the ground-based BEST, as well as part of the flight system.

7.3 RECOMMENDATIONS

At this point in time, the six most important candidate activities to support the development of a Life Sciences Laboratory capability are:

a. Carry-On Laboratory Definition Study.

b. Organism Holding Unit Development.

c. Organism Ground Support and Transfer Unit (BEST) Development.

d. Organism ECS/LSS Study.

e. Internal Centrifuge Definition Study.

f. Research Equipment Specification and Life Sciences Program Plans.

The relative importance of the Carry-On Laboratories has increased and represents the first step in the evolution of a Life Sciences Laboratory. The conceptual designs, as described in this phase of the study, require the background of a definition phase similar to that performed for the larger Life Sciences sortie module laboratories.

The organism holding unit, the ground support and transfer unit, and the organism ECS are basic to any proposed bio-research program. Organisms are the focal point of the research activity; therefore, those equipment items unique to the organisms must be developed as early as possible.

The interaction of the internal centrifuge to the research goals and laboratory designs is significant. Its definition is required at an early date so that the program will not be adversely impacted in the later stages of development, where changes would be costly.

As a result of this study, it appears that an overall specification describing the requirements for the development of experiment/research equipment is needed.

The proposed flight opportunities for Life Sciences research in the 1980 time frame requires that action be taken soon to develop a definitive program plan. The preliminary equipment unit development schedules, the physical integration within the sortie module, the performance of baseline ground controls — all indicate that about seven years are required prior to the flight date.